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DEVELOPMENT AND VALIDITY INQUIRY OF A RUBRIC FOR INTERDISCIPLINARY COMPETENCIES IN OCCUPATIONAL SAFETY AND HEALTH IN CAPSTONE PROJECTS OF CARERC PROGRAM GRADUATES

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DEVELOPMENT AND VALIDITY INQUIRY OF A RUBRIC FOR INTERDISCIPLINARY COMPETENCIES IN OCCUPATIONAL SAFETY AND HEALTH IN CAPSTONE PROJECTS OF CARERC PROGRAM GRADUATES

DISSERTATION

A dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the College of Education at the University of Kentucky

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ABSTRACT OF DISSERTATION

DEVELOPMENT AND VALIDITY INQUIRY OF A RUBRIC FOR INTERDISCIPLINARY COMPETENCIES IN OCCUPATIONAL SAFETY AND HEALTH IN CAPSTONE PROJECTS OF CARERC PROGRAM GRADUATES

Emerging demands in the field of interdisciplinary studies reveal a need for competent professionals who can apply their skills and experience to solving complex tasks of the workplace. This has placed inevitable demands on training institutions to adequately equip graduates to deliver on their mandate. Competency appraisal is an effective way to ensure proficiency in graduates. Meanwhile, transparent and valid rubrics provide opportunities for both students and trainers to continuously assess and evaluate the transfer of necessary skills.

This study focused on evaluating interdisciplinary competencies in Occupational Safety and Health (OSH) in the capstone projects of the CARERC program, a graduate and continuing education package that combines the academic resources of seven colleges of two major universities in Kentucky for research and training in the region. An Interdisciplinary Competency Evaluation Framework in OSH (ICER-OSH) was developed. The framework presented the complimentary interaction and orientation of the component competencies of interdisciplinary OSH. The Rubric in OSH (iCER-OSH) was built on the framework to confirm the “presence” or “not” of the relevant competencies in the capstone projects was developed from literature and program core-syllabi and was tested and calibrated using Rasch model. The psychometric evaluation of the rubric also supports the use of this tool for research and formative assessment in this population and related programs.

KEYWORDS: Interdisciplinarity, Interdisciplinary Competencies, Capstone projects, Rubric, Occupational Safety and Health

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DEDICATION

To Mrs. Gloriastene T. Agboola (Nee Thompson) of Louisiana, USA and Iree, Nigeria, who believed in me even when I was not sure of what I had and supported me to ensure I pursued those dreams. And to those upon whose shoulders I have lean to come this far.

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CHAPTER 1. INTRODUCTION

1.1 Overview

This dissertation is purposed to develop a valid rubric to evaluate interdisciplinary competencies in Occupational Safety and Health (OSH). The rubric will achieve this by confirming the "presence" or "not" of interdisciplinary competencies specifically in OSH. A valid rubric is a set of items in an instrument that helps teachers adequately measure the construct as conceived and ensure that the instrument can be utilized for confirming the presence of the construct wherever it is applied. It also helps learners have transparent guides of areas to concentrate in developing their skills in relation to the construct and it allows the program to confirm its effectiveness in delivering the goals associated with the construct. This rubric will fulfil all the above and ultimately meet a long-awaited gap in the field of interdisciplinarity and specifically interdisciplinary competencies in occupational safety and health. Overall, this study will contribute to the growing discourse on interdisciplinarity, especially adding input to the resolution of the challenge of assessment of interdisciplinary competencies.

Prior to this, despite various programmatic emphasis on training students to be competent interdisciplinary experts, there has been scarcity of rubrics specifically developed to probe for the presence of the interdisciplinary competencies developed in student's written reports, and especially capstones. Unfortunately, the CARERC program is not exempt from this malaise as it currently lacks a standard rubric to either assess or evaluate its goals of interdisciplinary competencies in its OSH. This study will therefore fulfil this long-awaited field deficiency and program desire to be able to assess and evaluate its effectiveness, interpreting transparently what components of OSH competencies to look for in students' written pieces as evidence that learning has taken place. Also, an aim like this aligns with the emphasis that improving the use of empirical data should guide rubrics' design and implementation (Panadero & Jonsson, 2020).

1.2 Background

The chapter sets out to provide an overview of interdisciplinary competencies in Occupational Safety and Health (OSH) as it relates to program level outcomes to set a foundation for the importance and relevance of a rubric development endeavor for a program. The Central Appalachian Regional Education and Research Center (CARERC) is one of 18 university-based occupational safety and health training programs sponsored by National Institute for Occupational Safety and Health/ Centers for Disease Control and Prevention (NIOSH/CDC). The CARERC combines the academic resources of five colleges at the University of Kentucky (UK) and two colleges at Eastern Kentucky University (EKU) to provide a fully equipped and recognized resource for occupational safety and health research and training in the region. All the programs within the CARERC culminate their objectives in capstone projects which are required to exhibit desired competencies hence justifying the investment in training and capacity development. The CARERC offers graduate programs and continuing education in Occupational Safety, Occupational Medicine Residency, Occupational & Environmental Health Nursing, Industrial Hygiene, Occupational Epidemiology, Occupational Athletic Training, Mining Health & Safety, and Agricultural Safety & Health.

To successfully complete the program, students in CARERC must execute a capstone project in which they demonstrate interdisciplinary competence and skills in gathering and analyzing data to address a specific research question, interpreting their results, communicating their research findings, and discussing the implications of their findings in the context of existing research and knowledge. Capstone research projects usually involve complex and diverse skills in a multidimensional task, typically involving analytical, methodological, and reporting components. However, there have been concerns about how to adequately assess both capstones and competencies, especially interdisciplinary competencies (Tripp & Shortlidge, 2020). Capstone research projects are prominent in many higher degree university courses assessment and have been used in initial medical training to assess research competencies. Capstone project experience set out to make experts out of students and to facilitate the intersection between research and practice's understanding. For the CARERC program, the focus is on the development of interdisciplinary competent graduates. Interdisciplinary competency compiles skills, abilities, and knowledge that individuals develop to successfully engage in tasks requiring complimentary contribution of multiple disciplines. More concisely, it is the ability to comprehend and demonstrate the learned ability in any given interdisciplinary work situation. Some of the skills would involve "taking a critical stand on disciplinary limitations, solving complex problems across disciplines, communicating across disciplines, handling interdisciplinary collaboration and teamwork, and using integrative potentials to create innovations" (Brandstädter & Sonntag, 2016; Lattuca et al., 2013; Pecukonis et al., 2008; Shen et al., 2015). Bromme (2000) opined that "individual competency needs to be specific for interdisciplinarity to explain success and failure in interdisciplinary work". Such specificity of interdisciplinary competencies points to an interpretative approach of competencies (Sandberg, 2000) "which emphasizes that competencies are mentally constructed by the meaning the employee makes of his or her work". This meaning develops with learning and grows with experience. In short, interdisciplinary competencies are learned instrumental behaviors, that empowers employees manage working across diverse disciplinary fields specific requirements. The specifics here are learned skills in occupational safety and health that the learner can demonstrate in relevant work tasks. Competencies as reflected above become easily obvious and assessable when subjected to a valid instrument. Such instruments must have detailed but concise domains and components that capture the essence of the construct and are expressed in rubrics.

Rubrics are extensively utilized for both summative and formative purposes used in classrooms at all educational levels across the globe. Although the empirical support for the benefits of using rubrics has been steadily growing, so have the criticisms (Panadero & Jonsson, 2020) like design and implementation limitations, inadequacy of sharing explicit criteria with students and consequent instrumental learning etc. Nonetheless, there is no more appropriate time than now to interrogate rubrics development, especially when program or task-specific rubrics are in great demand in order to meet project objectives.

A rubric denotes a matrix form that offers scaled levels of achievement or appreciation of a criteria set of or components of traits for a given type of operation, it could be oral or written presentation, or the use of collaborative skills. Rubrics of this nature index some gradations of quality to a expected or appropriate standard (e.g., to the performance of an expert or to the highest level of accomplishment evidenced by a particular cohort of students). “The descriptions of the possible levels of attainment for each of the criteria or components of performance are described fully enough to make them useful for judgment of, or reflection on, progress toward valued objectives” (Huba and Freed, 2000). Rubrics are assessment instruments designed for instructors to judge how student perform and at what level; learners themselves could employ it to have a transparent expectation of course objectives; “for teachers and learners to judge the quality and progression of student performance” (Panadero and Jonsson, 2020) and for evaluators to judge the effectiveness of a program. Thus, a effective and valid rubric for evaluating the “presence of” or “not” of interdisciplinary competencies as reflected or is reflective of what is in the capstone is essential to a holistic OSH work environment or programs and to fulfil a program’s obvious requirement. This would thus meet the CARERC evaluators’ need for an assessment instrument, present to students a transparent expectation of learning goals and provide the program with an evaluation scale.

Of the many studies that have reviewed rubrics, few have investigated rubric development (Reid et al., 2022); only one of the accessed studies added a review of any rubric designed to assess written research projects (Prins et al., 2017), an educational activity that may be very subjective when graded (Chong & Romkey, 2021; Williams & Kemp, 2019). Another review showed “faculty preferred more specific quality descriptions” when rubrics were used for written medical case reports and resulted in greater inter-rater agreement (Prins et al., 2017). Thus, it is evidenced “that rubric type related to measurement quality (particularly for research projects) is scarce” (Reid et al., 2022). In all, the need to collate empirical data to guide rubric design and implementation was noted (Panadero & Jonsson, 2020) especially written outcomes of projects (Reid et al., 2022). Particular to the CARERC program is the observed inconsistency within and across programs in submission formats of capstone project from students in the program, which makes assessment and evaluation of both written submissions and program goals complicated.

There is thus a substantial need to develop and establish some specific measurement properties of rubrics to be used to assess students' research projects. This becomes relevant especially in the CARERC training program. Despite that the emphasis of the program is to train students to be competent in interdisciplinary OSH, unfortunately, the program currently lacks a standard rubric to either assess or evaluate this aim. The goal of this study will therefore fulfil this long-awaited program desire to be able to assess and evaluate its effectiveness, interpreting transparently what components of OSH competencies to look for in student written capstone projects as demonstration that learning has taken place. An aim like above also aligns with the "perceived importance of improving the use of empirical data to guide the design and implementation of rubrics" (Panadero & Jonsson, 2020); and provides a template for transparent assessment designed on a consistent expectation of program learning outcomes. This study proposes to develop a rubric to both evaluate and offer transparent outcome expectations for capstone research projects prepared by graduates of the CARERC program and to establish its psychometric quality using Rasch Model. The rubric would be applied to evaluate the reflection or demonstration of components of interdisciplinary competencies in existing capstones thesis written by the graduates of the CARERC program.

1.3 Research Objectives

To be able to adequately evaluate interdisciplinary competencies in the written capstones of the program graduates, the first objective was to conceptualize a viable definition of interdisciplinary competencies from an extensive and systematic review of literature. This conceptualization would help identify relevant domains of interdisciplinary competencies and compile an approved skill set of desired domains in Occupational Safety and Health for the CARERC program. Also, a rubric that is suitable for evaluating the interdisciplinary competencies in Occupational Safety and Health from the completed capstone project thesis of CARERC program graduates was developed. Finally, the reliability and validity of the rubric was determined; that is, the extent to which it promotes a consistent measure of the reflection of the expected competencies in the different disciplines that enroll and complete the Interdisciplinary OSH Capstone project of students on the CARERC program.

1.4 Research Questions

To meet the objectives above, this study was guided by the underlisted research questions:

1. How does the literature compliment the expected interdisciplinary competences in Occupational Safety and Health (OSH) of graduates on the CARERC program?
2. What are the psychometric properties of the developed Interdisciplinary Competencies evaluation rubric in Occupational Safety and Health (iCER-OSH)?

In order to adequately answer the research questions above, the underlisted activities were conducted: First, an extensive systematic review of literature to conceptualize and develop an interdisciplinary competencies framework that identified the relevant domains especially in graduate degree programs of OSH was conducted. This was followed by the development of a quantitative dichotomous Rubric tool to measure the reflection or demonstration of interdisciplinary competencies in (OSH) in the completed capstone of CARERC program graduates. Finally, a psychometric analysis of the developed instrument to calibrate the rubric for this purpose was also conducted.

Mere design of a rubric without a confirmation of its ability to truly capture the extent of demonstration of the expected competencies would still raise concerns about its effectiveness for the program. To completely resolve this, a Rasch analysis was conducted to determine the quality of the developed interdisciplinary competencies rubric tool, asking how efficient and reasonable it is. “Rasch analysis is a psychometric technique that was developed to improve the precision with which researchers construct instruments, monitor instrument quality, and compute respondents’ performances. Rasch analysis allows researchers to construct alternative forms of measurement instruments, which opens the door to altering an instrument considering student growth and change. Rasch analysis also helps researchers think in more sophisticated ways about the constructs (variables) they wish to measure” (Boone, 2016; Reeves & Marbach-Ad, 2016).

This dissertation employed literature and extensive research done on interdisciplinary (competency sets using published literature, course objectives, and content summaries) competencies and rubric development to provide an evaluation rubric to see the extent to which the interdisciplinary competencies were reflected in the dissertations submitted to the CARERC capstone project and of other relevant interdisciplinary based programs. The motivation for this study was derived from both personal experience as a student and a future university educator who advocates consistent assessment and equity-based evaluation. Developing an interdisciplinary competent rubric for the CARERC project offers what is most needed for project-based goals, student success and development of the program. By applying the Biggs principle of Constructive Alignment (1996), I explored the intended learning outcomes of the CARERC program, used them to identify the relevant interdisciplinary competencies for the OSH and develop a rubric for evaluating the extent of reflection of the relevant competencies in the capstone projects of the CARERC students.

The study commenced with a review of the literature on interdisciplinary competencies plus the constituent structure of the instruments measuring them and the Rasch model-based framework of validation. It then proceeded to research methods, data analysis, results, and discussion. Finally, the conclusion gave a summary and critique of the findings, and areas for further research were identified.

CHAPTER 2. LITERATURE REVIEW

Program effectiveness can only be confirmed after an objective evaluation using reliable and valid instruments. This ensures that objectives and goals have been or are being achieved. In a training program in which learning has taken place, participant can demonstrate the skills and competencies expected of the learning and this ability to demonstrate learned skills supersedes all other perceived elemental rationale that people might make up for learner's assessment or evaluation of a program. Such evaluation provides students with a sense of what they know or do not know about a subject, teachers with assurance that learning progress is being made, policy makers that education is underway and stakeholders with confidence that program is fulfilling its intended goal. This feedback mechanism occurs in different settings and structure, programmed or not. Programmed structures, on the other hand, are usually designed with specific aims and goals in mind. Resources are sometimes invested into such specific areas of study or disciplines based on what are considered vital needs and those must be evaluated to ensure resources are not wasted. One such programmed structure is the CARERC program which has the intention of building deficient interdisciplinary capacity in the area of occupational safety and health.

2.1 Overview of the Central Appalachian Regional Education and Research Center (CARERC) Program

The demand for occupational safety and health services in the US is higher than the rate at which professionals are being turned out according to a NIOSH commissioned needs assessment (Westat, 2011). Worsening this is the approaching retirement age of experienced personnel. Thus, demand for professional occupational safety and health services continues to rise while training of competent professionals is at a comparatively slow pace. The story is not different locally, as critical needs are still observed in the 177 counties covered by CARERC program in eastern Kentucky, east Tennessee, West Virginia, and western North Carolina. “This region annually reports high proportions of occupational injuries related to transportation / highway incidents; production agriculture, forestry, fishing, and hunting; and mining, all of which are regionally important industries” (BLS-CFOI 2009, 2011, 2020). These preventable injuries are an attestation to the progressive dearth of competent hands to adequately cater to and proffer guidelines for a safe occupational environment (BLS-CFOI, 2020).

To significantly contribute to the arrest of this ongoing inadequacy of capacity locally, CARERC founded in 2012 specifically aims to:

1. Provide interdisciplinary occupational health and safety education for graduate students.

2. Develop student research skills in OSH.

3. Conduct interdisciplinary research on a variety of occupational diseases and injuries.

4. Deliver continuing education, consultation and outreach to address environmental and occupational safety and health concerns.

5. Translate her research and the research of others into practice to prevent injury and disease and their associated costs.

CARERC therefore provides education, training, and research support for master's and doctoral students in: Occupational Medicine Residency (plus MPH), Occupational/Environmental Health Nursing (DNP, PhD), Occupational Safety (MS at EKU), Industrial Hygiene (MPH at EKU), Occupational Epidemiology (MPH, PhD), Agriculture Safety and Health (MS, MPH, PhD), Mining Safety and Health (MS, PhD) and Occupational Athletic Training (PhD).

In providing these degree programs, CARERC combines the academic resources of four colleges at the University of Kentucky (UK) and Eastern Kentucky University (EKU) namely: the UK College of Public Health, the UK College of Engineering, the UK College of Nursing, and the EKU College of Justice and Safety. CARERC is one of only 18 such university-based occupational safety and health training programs funded by the Centers for Disease Control and Prevention and its National Institute for Occupational Safety and Health (CDC/NIOSH). It is the only Educational Research Centre (ERC) focused exclusively on the needs of Central Appalachia. The program meets the need mentioned earlier by training interdisciplinary competent professionals with the goal premised upon cooperation across different disciplines that comprise OSH and ensure they communicate, share knowledge, create linkages, and enhance coherence within and across the curriculum in order to achieve this lofty objective. Specifically, it endeavors to create opportunities that bring multiple disciplines together and integrate interdisciplinary efforts because interdisciplinarity results in and breeds innovation (Olcese et al., 2014). CARERC has as its main goal interdisciplinarity in occupational safety and health and thus fits both the needs and is best poised. Overall, CARERC graduates culminate their studies in capstone projects.

Table 2.1 shows the distribution of the submission as it relates to the discipline, program and number of chapters of the 35 submitted capstone projects to the program repository. The distribution immediately attests to the variety that may be peculiar to discipline or program writing style and holds a lot of challenge to the evaluability potentials of the capstones submitted to the program.

Table 2.1 Summary of distribution of submissions to the CARERC program

No of chapters	Frequency of Occurrence					
No of chapters	MSC Occupational Safety)	MSC (Mining and Health Safety	MPH Agricultural Health & Safety (Environmental Health)	MPH Occupational Epidemiology	DPH Occupational Epidemiology	PhD Occupational & Environmental Health Nursing
1						
3		1	1			
4		1	6			
5	4		5	4	4	1
6	1		5	1		
10		1				

2.2 Overview of Interdisciplinary studies

An anthology was published in 1979 following a postdoctoral seminar on interdisciplinarity at the Interdisciplinary Graduate program in the Humanities of Pennsylvania State University between 1975 and 1976. The seminar was aimed to promote among participants a better understanding of contemporary interdisciplinary movement through the discussion of basic issues. Authors emerged from this meeting with obvious assumptions and little care for details, they use varying terminologies including reference to two non-disciplinary projects and presuppositions that everyone understood the history, content/context, and development of interdisciplinarity. Needless to say, that the situation has not really changed until now. Notwithstanding, this anthology laid the foundation for the richness of opportunities and challenges that could arise from interdisciplinary innovations (Kockelmans, 1979, p vii). Kockelmans started his chapter on "Why Interdisciplinarity" with a plea for a more uniform terminology, one that seems to be both adequate and unambiguous. Many efforts followed to decipher and adequately situate interdisciplinary endeavors. Among the earliest was Kavalovski (1979) who started by describing the "key goals of interdisciplinary education as the integration of knowledge, freedom of inquiry, and innovation". Newell and Green (1982/1998) complemented his submission but advised that deductive reasoning, reasoning by analogy and particularly synthetic thinking should be added to the list above. Later, Newell (1998, 2002) identified 21 possible cognitive skills for integrative work, which includes critical thinking, sensitivity to bias and ethical issues. Similarly, in their perception of effective interdisciplinary learning, Lattuca et al. (2004, p. 44) referred to outcomes such as "promoting the development of sophisticated views of knowledge and learning" and "building students' capacity to recognize, evaluate, and use differing (multiple) perspectives". Highlighting general cognitive skills indicates that the authors above focused on issues relevant to both disciplinary and interdisciplinary work. Unfortunately, it seems restricted just to ability to shed light on the substantive knowledge base of student understanding and the unique demands of disciplinary coordination (Boix Mansilla &Duraising, 2007). Yet these literatures failed to make any attempt at validating their claim with any empirical proof like Wolfe and Haynes (2003a, 2003b) did in their "construct validation of a scoring rubric for expository, research-based interdisciplinary writing". Their rubric presented 55 criteria, including drawing on disciplinary sources, critical argumentation, multidisciplinary perspectives, and interdisciplinary integration. From the outset, the rubric displayed high inter-rater reliability, but came with two limitations, viz: disciplinary reasoning was assessed solely by examining students' use of sources, and the multiple criteria appeared very cumbersome for a feasible rubric. Notwithstanding the above, the explanations of interdisciplinarity cannot be discarded, rather further studies are recommended to ascertain their contributions and the relevance of the Components.

Closely associated with the above and complimenting disciplinary grounding is disciplinary humility mooted by Byrne et al. (2016). Every venture at attempting to commence work across disciplines must begin with "developing a mindset, or epistemic perspective, that is infused with humility, inclusivity, and respect for other disciplinary epistemologies" (Tripp & Shortlidge, 2019). This is considered "prerequisite to and basis for transdisciplinary conversations and transcendent knowledge generation" (Byrne et al., 2016, p. 14). The phrase "disciplinary humility" was adapted and applied to interdisciplinary understanding, in order to work across disciplines, it is imperative to remain reflexive about one's limitations in knowledge, skill, and awareness of personal biases (NRC, 2015). To ensure respectful evaluation of similarities and differences of discipline and persons, all metacognitive efforts should begin by infusing disciplinary humility into learners' mindsets at the inception of interdisciplinary thinking, research, and collaborations, making them realize the limitation of a single discipline to and how interconnected disciplines must be to solve complex human problems. (NRC, 2003, 2009; AAAS, 2011; Bammer, 2013). This theme has also seen various modifications and is now missing in recent interdisciplinary studies. Other ways competencies have been muted are taking a critical stand on disciplinary limitations, solving complex problems across disciplines, communicating across disciplines, handling interdisciplinary collaboration and teamwork, as well as using integrative potentials to create innovations (Lattuca et al., 2013; Shen et al., 2015; Brandstädter & Sonntag, 2016).

Varied indicators/components and attempts at defining interdisciplinarity by different studies/authors are summarized in Table 2.2. The components as presented in the definitions in Table 2.2 will contribute in varied proportions to the overall understanding and eventual indicators of interdisciplinary competencies in this study.

Table 2.2 Summaries of the Components of Interdisciplinarity by Authors

Interdisciplinary Learning Objectives (Newell et al., 1990)	Interdisciplinary Learning Objectives (Field, 1994)	Interdisciplinary Learning Objectives (Cornwell & Stoddard, 2001)	Eight Components of interdisciplinary competence (Lattuca et al., 2012)	Interdisciplinary assessment practices (Drake & Reid, 2017)
• Sensitivity to ethical issues, • Enlarged perspectives or horizons, • Ability to synthesize or integrate, • More creative, original or unconventional thinking, • More humility or listening skills, • Sensitivity to bias.	• Tolerance of ambiguity or paradox, • Critical thinking, • A balance between subjective and objective thinking, • An ability to demythologize experts, • Increased empowerment.	• The ability to see new and different questions and issues, • The ability to draw on multiple methods and knowledge sources to address problems.	• Awareness of disciplinarity • Appreciation of disciplinary perspectives • Appreciation of non-disciplinary perspectives • Recognition of disciplinary limitations • Interdisciplinary evaluation • Ability to find common ground. • Reflexivity • Integrative skill	• Increased depth and diversity in classroom assessment • Increased efficiency in classroom assessment • Deepening assessment literacy • Challenge of reporting result to student

The word interdisciplinarity has been extremely exhausted in literature as reflected by the summary of the components of interdisciplinary work by different authors as shown in the table above, although rarely is there a consensus definition (Blom et al., n.d.). Also, the varieties observed in definition seem to relate to differences in context in which the term interdisciplinarity is being used such as research, education, social sciences, or sciences, etc. (Claus & Wiese, 2019). Compounding the confusion is the different definitions for interdisciplinarity that are often used interchangeably with transdisciplinarity, crossdisciplinarity or multidisciplinarity. These confusing terminologies are delineated in a later section. It is thus important that individuals working in the interdisciplinary field are aware of the different definitions and actively prevent confusion (Boix Mansilla & Duraising, 2007). Despite the obvious lack of consensus, Stein (2007) observed that there seems to be an agreement that interdisciplinary work is based on the integration of multiple (at least two) disciplines. A literature review on the essence of interdisciplinarity also showed that collaboration is essential (Tripp & Shortlidge, 2020, Gardner & Boix Mansilla, 1994; Boix Mansilla & Gardner, 2009). Boix Mansilla and Duraising, (2007) considered disciplinary grounding as a prerequisite for effective interdisciplinary work, they explained that students must have the basic understanding, a provisional grounding or understanding in a particular discipline before they can draw the links between disciplines. While clearly desirable, assessing the disciplinary foundations of students' work is not always easy as there was no consensus on which aspect (epistemology, hypothesis, information, methodology etc.) of the discipline was to be assessed, “while the danger of students going meta too quickly by focusing on epistemology and methodology at the expense of more substantive disciplinary understanding is also of great concern" (Borrego et al., 2009).

Interdisciplinary theorists Klein and Newell have persuasively debated that "interdisciplinary study is not a simple supplement but is complementary to and corrective of the disciplines" (Klein & Newell 1998, p. 3). Thus, disciplines form the foundation of interdisciplinarity; to engage in interdisciplinary study, one must have a clear understanding of disciplines. Tripp & Shortlidge's (2020) approach to first define what a discipline is before proceeding to delve into any interdisciplinary venture becomes very instructive as it would set the proper foundation based on the perspective above. They agreed with Newell and Green's (1982) description of a discipline as "a particular branch of learning or body of knowledge that can be distinguished by several factors, including the questions it asks via its ontological lens, epistemology and methodology regarding how these ideas are used to contribute to a body of knowledge composed of concepts, theories and facts". Stein in his own study, adopted Gardner's (2000) definition of a discipline as "the concepts and methods for thinking about specific types of questions and phenomena; concepts and methods that have been cumulatively accepted by experts as providing standards for determining the validity of answers". Consolidating the above, disciplinary understanding was considered to "build on knowledge and modes of thinking that have survived the scrutiny of expert communities using commonly agreed upon methods and validation standards" (Gardner & Boix Mansilla, 1994; Boix Mansilla & Gardner, 1999). Although disciplinary perspectives are a build-up on discipline and represent "established bodies of knowledge and modes of thinking within one academic or occupational field, it facilitates work processes within a discipline”. Yet, Sung et al. (2003) observed that the same perspective could also hinder cooperation across disciplines. Therefore, they could also be a major challenge in achieving and assessing interdisciplinary issues. The above demands that the relationships bearing the details of the interactions of the integral disciplines must be adequately understood for a fruitful discussion on interdisciplinarity (Swoboda, 1979).

Mentkowski and Sharkey (2011) also studied the advancement of interdisciplinary research and teaching by focusing on “integrative and applied learning and what still needs to be done to better integrate interdisciplinary education in the disciplinary curriculum”. Their goal was to identify multiple factors that influence the education and assessment of integrative learning. Following their multi-campus team initiation, they started by agreeing on a basic definition of integrative and applied learning; “Integrative learning and applied learning is an understanding and a disposition that a student builds across the curriculum and co-curriculum, from making simple connections among ideas and experiences (integrative learning) to synthesizing and transferring learning to new, complex situations within and beyond the campus (applied learning)” (Rhodes, 2010). In a participant’s view and in consonant with the above, “interdisciplinary integration should be driven by the problems that we mean to tackle rather than be pursued for its own sake” (Boix-Mansilla & Duraising, 2007): Therefore "students have to know enough of the things that they should know from each of those disciplines to be able to do interesting, important work." Faculty also recognized that unlike their disciplinary counterparts, “the products of interdisciplinary work should connect with multiple-often conflicting-disciplinary audiences”. The authors further agreed with previous work that both integrative and applied learning are essential for students to develop interdisciplinary expertise (Feltovich et al., 2006) and, if a faculty wants to teach and assess integrative and applied learning, “it is important to realize that knowing and doing are strongly connected”. Both aspects of learning develop together in a cyclical fashion. The team also noted that performance in an interdisciplinary field needs to develop, and that this growth can be assessed by defining teachable abilities which Mentkowski and Sharkey (2011) defined as “multidimensional learning outcomes that ultimately involve students’ integration of knowledge and understanding, behaviors and skills, attitudes and self-perceptions, motivations and dispositions and habits of mind and value.” (Based on Anastasi, 1980; Sternberg, 1998). While also defining the learning objectives it became clear to the author (Repko, 2008) that the process of integration is essential for interdisciplinarity and interdisciplinary programs. Therefore, the development of good synthesis and integration skills should play a central role in interdisciplinary learning.

Repko also acknowledged that certain learning objectives in addition to the above such as critical thinking, a complement to integration may be either disciplinary or interdisciplinary learning objective depending on the perspective. In cases like this, the learning objective must be defined in such a way that the development of the skill clearly demands an interdisciplinary view and attitude. The summary of Repko perception of Interdisciplinary Cognitive Capacities (Repko, 2008) becomes instructive here, forms the foundation of many interdisciplinary studies and is presented in Table 2.3 of interdisciplinary cognitive capacities below:

Table 2.3 Interdisciplinary Cognitive Capacities

Development and application of perspective-taking techniques (Repko, 2008)	**1. Development of structural knowledge of problems appropriate to interdisciplinary inquiry**	**2. Integration of conflicting insights from two or more disciplines.**	**3. Development of cognitive advancement or interdisciplinary understanding of a problem**
i. Understanding multiple perspectives to be able to solve a certain problem, including disciplinary-based viewpoints	1. Development of structural knowledge, i. Understanding of higher order relationships and organization of principles, ii. Knowledge obtained from different knowledge domains or disciplines, iii. The ability to critically view relationships between relevant disciplinary perspectives, iv. Resulting in a better cognitive analysis of the core theme. 2. Obtaining declarative knowledge (factual information), 3. Obtaining procedural knowledge (process-based information), ii. Being able to use declarative and procedural knowledge to solve problems, iii. Forming a conceptual framework. i. Complex internalized organization of knowledge, ii. Contains most relevant perspectives, concepts, ideas and methods of a discipline, iii. Framework gives meaning and connects different perspectives, concepts, ideas and methods, iv. Helps determine when and how a set of declarative facts should be applied to a particular situation.	iv. Enhanced capacity to integrate conflicting insights from two or more disciplines,	The ability to explain a phenomenon, solve a problem, produce a product or formulate a new question which would not have been possible by solely using the knowledge from one discipline, and results in interdisciplinary understanding and/or cognitive advancement. 1. Underlain by four core premises: 2. Built on a performance view of interdisciplinary understanding, with the ability to utilize. knowledge is more important than simply gaining knowledge, 3. The interdisciplinary understanding stems from disciplinary expertise, 4. The interdisciplinary understanding results from integration of disciplinary perspectives, Interdisciplinary understanding is purposeful and results in cognitive advancement (e.g. explanation of a phenomenon, production of a product, generation of new insights, raising new questions or offering an explanation).
	Assembling new sets of potential solutions to a given problem	Identification and blending of knowledge from relevant disciplines to produce a more comprehensive understanding of a particular problem.	

Arguably all student work, interdisciplinary or otherwise, is (or should be) aimed at advancing student understanding. Moreso, interdisciplinary work advances an understanding that capacitate students to use knowledge flexibly and produce outputs that push beyond disciplinary boundaries; rather than knowledge accumulation, capacity to think with information at hand when confronted with novel solutions is the expectation here (Boix Mansilla & Duraising, 2007). In interdisciplinary work, students advance their understanding by moving to a new conceptual model, explanation, insight, or solution. To do so, they employ the unique advantages afforded by bringing together more than one disciplinary lens. Interdisciplinary work requires a deliberate intertwining of disciplinary perspectives and an assessment of disciplinary insights for their potential contributions and limitations. Thus, knowledge advancement became another core of interdisciplinarity agreed upon by different authors.

Klein & Newell (1998) proceeded to define “interdisciplinary studies as a process of answering questions, solving problems or addressing a topic that is too broad or complex to be dealt with adequately by a single discipline or profession”. A cardinal element of this definition is the integration of more than one discipline and proffering solution to a problem. In what appears to be a step forward, interdisciplinary understanding was defined as “the capacity to integrate knowledge and modes of thinking in two or more disciplines or established areas of expertise to produce a cognitive advancement—such as explaining a phenomenon, solving a problem, or creating a product—in ways that would have been impossible or unlikely through single disciplinary means" (Boix Mansilla et al., 2000). To further clarify the grey areas around understanding interdisciplinarity and focusing more on summative evaluation than process, Boix Mansilla & Duraisingh (2007) interviewed faculty in interdisciplinary undergraduate programs and developed three criteria for assessing interdisciplinary work: (a) disciplinary grounding, (b) integrative quality, and (c) critical awareness. They defined interdisciplinary understanding as "the capacity to integrate knowledge and modes of thinking in two or more disciplines to produce a cognitive advancement e.g., explaining a phenomenon, solving a problem, creating a product, raising new questions; in ways that would have been unlikely through single disciplinary means". Also central to their definition is the "upholding of disciplinary standards in interdisciplinary work. Disciplinary understanding builds on knowledge and modes of thinking that have survived the scrutiny of expert communities using commonly agreed upon methods and validation standards" (Gardner & Boix Mansilla, 1994; Boix Mansilla & Gardner, 1999). Boix Mansilla & Duraisingh (2007) drafted another, slightly different definition of interdisciplinary understanding, that is widely used now as "the skill to integrate knowledge and modes of thinking from two or more disciplines which results in a cognitive advancement, such as the explanation of a phenomenon, solving a problem or producing a product, which would not have been possible if solely the knowledge of one discipline had been used". "understanding" is viewed here in a "performance" sense as the capacity to use knowledge flexibly and effectively (application and thinking of the knowledge), rather than having or accumulating it (Perkins, 1998). Advancing understanding therefore requires that learners are offered the opportunities to apply or think with the knowledge learned; consequently, it entails providing the room to build and demonstrate understanding and seeking assessments that adequately measure this understanding. It becomes obvious that as individuals engage in meaningful learning, they progressively restructure their knowledge, ultimately constructing complex frameworks of interrelated concepts with many levels of hierarchy, branching, and crosslinking efforts to push a form of advancement in understanding. Evidence suggests that expertise in academic disciplines is reflected in the depth and complexity of an individual's knowledge frameworks, which in turn enhance a person's ability to use knowledge and to draw scientifically valid inferences and conclusions (Quinn et al, 2003). From these perspectives, individuals understand a concept when they can apply it-or think with it-accurately and flexibly in novel situations.

There have been attempts to map out typologies of interdisciplinarity (Krishnan, 2009; Barry, 2007). Yet these studies were often pessimistic in their conclusions: working with colleagues who are coming from very different epistemological starting points and bringing together different types of data can be complicated. Barry points out the difficulty of assessing the productivity of such projects (Barry, 2007: 24). However, it was suggested that this is because in proposing interdisciplinarity as an end or outcome such assessments are aiming for unattainable goals. Instead, focus was shifted to propose interdisciplinarity as a research stance. Where research findings could be predicted and then the need for research is defeated already. Therefore, he argued that interdisciplinarity is likewise better treated as a process and not an outcome. Doing interdisciplinarity means going into unknown territory, and to propose to be doing so according to a model to be assessed as an output would be unnecessarily restricting. The confusion around interdisciplinarity is thus better resolved by viewing from different perspectives ranging from scope to context.

A foremost perspective was that “interdisciplinary research may range from simple communication of ideas to the mutual integration of organizing concepts, methodology, procedures, epistemology, terminology, data, and organization of research and education in a large field."(OECD, 1998). The aim of interdisciplinary research is not simply to fill gaps in knowledge but to potentially produce new spaces for knowledge/ways of knowing. This is not to argue for a new post-disciplinary view of the world, but to suggest that the ontologies of the different disciplines need to be viewed critically, reflectively, and relationally. This if proposed can be best achieved by engaging interdisciplinarity as a research design tool rather than as research outcome (Pink et al., 2019). Summarily, the above emphasized that ‘interdisciplinarity’ is a process rather than an outcome. Aboelela et al., (2007) came up with key definitional components below from literature for interdisciplinary research:

- “Qualitatively different modes of interdisciplinary research
- Existence of a continuum of collaboration (“interaction may range from simple communication of ideas to the mutual integration of organizing concepts,

methodology, procedures, epistemology, terminology, data, and organization of research and education in a fairly large field."(OECD, 1998)

- Definition and fidelity to disciplinarity ("thought domains" [Aram 2004], "specific body of teachable knowledge" [Woollcott 1979], "conceptual specificity" [Robertson et al., 2003], or "journal sets" [Morilloe et al., 2003]) or by social factors (e.g.,"isolated domains of human experience possessing its own community of experts" [Nissani 1997], or "self-regulating and self-sustaining communities" [Lattuca, 2002]).
- Degree of cooperation or interaction
- Degree of communication and sharing (existence of a continuum from multidisciplinary to interdisciplinary to transdisciplinary was apparent)

➢ Outcome of the collaboration (could be product or process (social scientist's perspective)" (Aboelela et al., 2007)

A preliminary definition of interdisciplinary research was therefore developed, based on the key themes and continuum identified in the literature search as:

> "Any study or group of field anddertaken by scholars from two or more distinct academic fields, based on a conceptual model that links or integrates theoretical frameworks from those disciplines, using study design and methodology that is not limited to any one field and requiring the use of perspectives and skills of the involved disciplines in all phases from study design through data collection, data analysis, specifying conclusions and preparing manuscripts and other reports of work completed" (Aboelela et al., 2007).

The US National Academies are not unconcerned as they also drafted a definition of interdisciplinary research (IDR) as

> “A mode of research by teams of individuals that integrates information, data, techniques, tools, perspectives, concepts, and/or theories from two or more disciplines or bodies of specialized knowledge to advance fundamental understanding or to solve problems whose solutions are beyond the scope of a single discipline or area of research” (National Academies, 2005).

It is very clear from the above that the mere addition of researchers from various disciplines or with different academic and professional credentials is not sufficient to make a research effort interdisciplinary. Rather, deeper evidence of integration including critical analysis of the conceptual framework, study design and execution, data analysis, and conclusions can be used to establish the true degree of interdisciplinarity.

The definitions of Boix Mansilla and Duraising (2007), despite laying a widely accepted foundation for interdisciplinarity and holding sway for a while came under scrutiny when Tripp & Shortlidge (2019) raised the concern of adequately assessing “Understanding” which was the core of the “Targeted Assessment Framework” that underlaid Boix Mansilla et al’s (2009) definitions and studies. During their study, while reviewing the definitions of Boix Mansilla et al (2009, p. 219) and NASEM (2005), they concluded that the main difference between the two definitions lies in their objective: the former describes a way of understanding, while the latter involves the application of interdisciplinary research. Also, as the definitions are derived from interdisciplinary understanding in the social sciences and interdisciplinary research in the natural and physical sciences, respectively, they resolved to craft a definition focused on what interdisciplinary science might seem like in the context of undergraduate science students. Tripp & Shortlidge (2019) proceeded to propose what they considered a more encompassing definition of interdisciplinary science following a faculty survey across scientific disciplines and departments (faculty members and scientific organizations), asking, "How do you define interdisciplinary science?" and content analysis of 184 open-ended survey responses resulting in six salient themes. They projected that:

> "Interdisciplinary science is the collaborative process of integrating knowledge or expertise from trained individuals of two or more disciplines by leveraging various perspectives, approaches and research methods/methodologies – to provide advancement beyond the scope of one discipline's ability".

Five of the six salient themes from faculty responses contributed to the above definition of interdisciplinary science and contain constituent parts from previously presented definitions from the social sciences literature and scientific research funding agencies. A common theme to their definition and NASEM's but lacking in Boix Mansilla et al's (2009) is that interdisciplinarity involves "collaboration". The relevance of this theme is supported by a study that explored learning outcomes for graduate students involved in the NSF's (former) Integrative Graduate Education and Research Traineeship (IGERT) program (Borrego & Newswander, 2010). Beyond collaboration being found important to interdisciplinary science, all three definitions are almost the same. This explains the fact that researchers, whether science-focused or not are aware of the requirements of interdisciplinarity.

Furthering the discourse, to measure undergraduate students' interdisciplinary science thinking, Tripp & Shortlidge (2020) developed an Interdisciplinary Science Rubric (IDSR). In previous papers, the focus was on the development of an Interdisciplinary Science Framework (IDSF) (Tripp & Shortlidge, 2019) and they evaluated an often-used interdisciplinary rubric developed for the Social Sciences and Humanities by Boix Mansilla et al. (2009) focused on "interdisciplinary understanding". They concluded that this rubric did not fully measure the assessment criteria from the IDSF with respect to the writing activities in science courses. Tripp & Shortlidge (2020) also reported that in terms of assessment, "understanding" is a nebulous term which is difficult or impossible to measure. They therefore indicated that interdisciplinary thinking is more accurate in describing the purpose of a rubric. In addition, they modified two other constructs used by Boix Mansilla et al (2009) in their rubric (purposefulness and critical awareness were changed to objective and broader awareness respectively). It is difficult to agree with their conclusion since assessors can draft assessment measures that will effectively assess any competency if appropriately reflected on. With these modifications, Tripp & Shortlidge (2020) developed the IDSR and indicated that the newly proposed constructs are better able to measure a students' ability "to think in an interdisciplinary way when considering how to address real-world problems". This affirms that the integration of disciplinary perspectives is a means to a purpose, not an end in itself, and that multiple possible integrations are viable. The merit of an integration is to be assessed against the very purpose of each interdisciplinary enterprise. Consequently, no standard metric applies to work produced for a variety of aims. Instead, a dynamic framework is needed, one that calls attention to the purpose of a particular piece of work as a benchmark by which to judge its successes and limitations. The main challenge between Tripp and Shortlidge interdisciplinary rubric and Boix Mansilla's is adequately assessing understanding.

Tripp et al. (2020) surveyed a sample of science faculty to understand how they currently assess students' interdisciplinary science understanding. They observed that individual writing-intensive activities are the most frequently used assessment type (69%). To further understand how writing assignments can accurately assess students' ability to think interdisciplinarily, a preexisting rubric, designed to measure social science students' (Boix Mansilla et al., 2009) was explored to assess writing assignments from 71 undergraduate science students. Complementing this were semi-structured interviews conducted with 25 of those students to explore similarities and differences between assignment scores and verbal understanding of interdisciplinary science. They concluded from the study that certain constructs of the instrument did not fully capture this competency for the population and suggested an interdisciplinary framework may be a better model to guide assessment development of interdisciplinary science called Interdisciplinary Science Framework (IDSF). In the same vein, AAAS, 2011 Vision and Change report had emphasized interdisciplinary understanding with recommendations that "future scientists must be equipped with a skill or competency set that enables them to effectively address problems that span multiple disciplinary domains". Also, that the ability to "tap into the interdisciplinary nature of science" is one of the competencies that science educators must work to incorporate into curricula. Meanwhile, Boix Mansilla et al. (2009) defined this interdisciplinary understanding as "the skill to integrate knowledge and modes of thinking from two or more disciplines which results in a cognitive advancement, such as the explanation of a phenomenon, solving a problem or producing a product, which would not have been possible if solely the knowledge of one discipline had been used" as a major requirement to develop Interdisciplinary competencies. In a prior study though, this competency was dubbed difficult to operationalize and evaluate (Tripp & Shortlidge, 2019). Overall, they opined that the IDSF should aid instructors in establishing learning goals and outcomes related to interdisciplinary science, guiding the development and assessment of interdisciplinary work in undergraduate science education. These insights combined with multiple research methods and collaboration across disciplines were the groundwork for the IDSF, whose five core criteria are disciplinary grounding, advancement through integration (Boix Mansilla et al., 2009), disciplinary humility (Byrne et al., 2016), different research methods and collaboration across disciplines (Tripp & Shortlidge, 2019).

Progressing from interdisciplinary understanding/research to a mindset shift into a competency-focused perspective suggested a form of instilling interdisciplinary habits of mind by using strategies for active learning and reflective thinking (Newell & Luckie, 2019). Since the central objective of interdisciplinary courses is not to fit students into the status quo but to empower them to function effectively in a complex evolving world, it thus become imperative that both pedagogy and assessment criteria must be designed in such a way that it introduces learners to habits of mind that permit interdisciplinary thinking. This becomes relevant as we observe that most definitions of competence would include the habit of an individual, which would enhance the easy transformation into a competent interdisciplinarian. These habits of mind as reflected in Table 2.4 with other themes of interdisciplinary works could serve as foundation for the identification and definition of relevant competencies for interdisciplinary occupational safety and health. For such a competency-focused understanding of interdisciplinary work, Claus & Wiese (2019) also proposed a self-report instrument for the new model of interdisciplinary competencies, which is parsimonious and specific for interdisciplinary collaborations. As such, it advances previous work and identifies relevant competency components. The clear focus on competencies is also apparent in the self-report measure they developed. Despite the consistency of results across different research methodologies to achieve the study objective the self-reported data for competencies presents a major limitation to the study. Notwithstanding, this effort aligns elements of previous works to competencies specific to interdisciplinarity.

In summary, the components that will adequately define interdisciplinary work would be contextual, collaborative, integrating and spanning continuum. This study intends to conceptualize its definition to adequately capture these identified perspectives and present a competency-focused measure of interdisciplinary engagement in Occupational Safety and Health in the CARERC program

Table 2.4 Interdisciplinary habits of mind

1. Drawing insights from diverse perspectives into complex issues	**2. Evaluating insights**	**3. Modifying insights**	**4. Integrating insights into comprehensive understanding of issues (Newell & Luckie, 2019)**
Strive for adequacy	Assume every disciplinary perspective has at least one kernel of truth	Seek commonalities do not compromise	Look for unexamined linkages and unexpected effects
Seek out diversity of perspective	Assume whatever you're attempting has probably been tried before	Think holistically, contextually, and systemically	Seek unanticipated effects by re-contextualizing
Identify perspective	Proceed methodically	Think dualistically	Expect multiple causes and effects,
Identify pertinent knowledge and information	Bracket and set aside/suspend personal convictions	Embrace contradiction	Resist the urge to assign numbers to things not inherently quantitative
In interdisciplinary collaborations, be alert to relevant approaches of other team members and their disciplines.	Recognize all sides of an argument	Use techniques for judging conflicts between disciplinary insights in order to create common ground.	Don't fall in love with a solution until you understand the full complexity of the problem
	look for strengths in arguments you dislike and weaknesses in those you like.		Strive for balance, integrate as you go, and Value intellectual flexibility and playfulness,

2.3 Emerging Components of Interdisciplinary studies

Strongly emerging from the studies above, a set of themes are required for work to be termed interdisciplinary. These themes underlie the basis for the specification of the competencies necessary for an individual researcher to move from accomplishment in his/her original discipline to successful participation in interdisciplinary work. Combining the competencies pinpointed in these papers will give us an idea of what a student should learn and master to become a disciplinarian well capable of working in multidisciplinary teams to achieve interdisciplinary solutions to complex problems. Focus on these needed competencies can then drive team development within established interdisciplinary centers and training programs for the next generation of interdisciplinary scholars. Important overlaps and connections exist among these themes, and distinct categories that reflect the descriptions are underway. When combined, the themes from the definitions above and related literature identify emerging themes relevant to interdisciplinary process and evaluation, highlighting the process of resolving conflicts between disciplines and creating common ground. The underlisted themes serves as the summary of the many fostered by literature as they subsumed and capture almost other themes and subthemes in different degrees:

2.3.1 Disciplinary Grounding

Disciplinary grounding is defined as “the degree to which student work is grounded in carefully selected and adequately employed disciplinary insights” (Boix Mansilla & Duraisingh, 2007, p. 222). This is a prerequisite provisional grounding or understanding for learners before they can draw the links between disciplines. Boix Mansilla & Duraisingh (2007) reported that faculty experts felt that students did not need to master each of the contributing disciplines but that they did need enough depth to reflect on the nature of disciplines and make meaningful connections. Similarly, Repko (2008) cites a willingness to achieve “adequacy” in multiple disciplines as an important distinguishing quality of an interdisciplinarian, and Borrego et al. (2009) emphasize disciplinary grounding for engineering students in interdisciplinary learning environments. While clearly desirable, assessing the disciplinary foundations of students' work is not always easy as there is no consensus on which aspect (epistemology, hypothesis, information, methodology etc.) of the discipline is to be assessed, while the danger of students exceeding scope too quickly by focusing on epistemology and methodology at the expense of more substantive disciplinary understanding is also of great concern.

Interdisciplinary theorists Klein and Newell have convincingly argued that “interdisciplinary study is not a simple supplement but is complementary to and corrective of the disciplines” (Klein & Newell 1998, p. 3). Thus, disciplines form the foundation of interdisciplinarity. In order to engage in interdisciplinary study, one must have a clear understanding of disciplines. Boix Mansilla & Duraising (2007) suggested that “assessing interdisciplinary work involves carefully considering its disciplinary grounding by a focus on selection (of disciplines and insights) and appropriateness (in the use of knowledge and modes of thinking)”. Are the selected disciplinary insights fit to inform the issue at hand? Are any key disciplinary perspectives missing? Are the considered theories, examples, findings, methods, and forms of communication employed in accordance with their disciplinary origins, or does the work exhibit misconceptions? Close disciplinary reading of student work should unearth the foundational bodies of expertise on which a piece stands. Targeted and informative feedback then becomes possible. It should also be noted that the questions about the limitations that power and privilege in a discipline in higher education can foment were raised, but logical means to work around such constraints were also suggested (Borrego & Newswander, 2010). This theme serves as a core to the definition of any interdisciplinary endeavor as it has remained a constant component in all interdisciplinary studies. Questions raised are to assure that these themes are seen grounded in critical awareness and thinking, inquiry and analysis, intercultural competence etc.

2.3.2 Advancement through integration

Interdisciplinarity has been defined as a study that "draws on disciplinary perspectives and integrates their insights through construction of a more comprehensive perspective" (Klein & Newell 1998, p. 3). Thus, integration is typically seen as the litmus test of interdisciplinarity despite non-consensus in definition. Yet, as Field & Stowe (2002) have pointed out, "consensus on the meaning of synthesis or integration does not exist" (p. 263). Credit should be given only if the theory, paradigm, or perspectives arises in different disciplines, and a reasonable reader from the target audience would find the application of each disciplinary approach adequate for an undergraduate student within each discipline. However, it is not necessary for the approach to be integrative (Wolfe and Haynes, 2003). The above position by Wolfe and Haynes undermines the importance of integration which has become a core of interdisciplinarity and may reflect the extent of understanding of the concept as confused with other terminologies.

In a participant's view, interdisciplinary integration should be driven by the problems that we mean to tackle rather than be pursued for its own sake (Boix-Mansilla & Duraising, 2007). The same study found that "students must know enough of what they should from each of the complimentary disciplines to be able to execute a valid interdisciplinary work. Faculty also opined that "unlike disciplinary outputs, the products of interdisciplinary work should connect with multiple-often conflicting-disciplinary audiences". In interdisciplinary work, students take their understanding to a new conceptual model, explanation, insight, or solution. To do so, they employ the unique advantages of having more than one disciplinary lens and platform. Interdisciplinary work requires a deliberate intertwining of disciplinary perspectives and an assessment of disciplinary insights for their potential contributions and limitations.

In advancement through integration, assessing the integrative qualities of a piece of work involves identifying points of disciplinary integration and articulating the cognitive advantage enabled by the combination of perspectives. Going by the 2007 study addressing epistemic qualities of student work, sixty eight percent of the faculty identified "synthesis" or "integration" as an essential feature of interdisciplinary work, often in association with innovation. One was quoted describing interdisciplinary work as taking "a tool set from one discipline and very rigorously and thoroughly applying it in a place where its application was not invited or anticipated" (Boix-Mansilla & Duraisingh, 2007). Determining the degree to which students' understanding has been advanced by interdisciplinary work presented predictable challenges, the greatest of which concerns the assessment of the demand for integration, the precise articulation of how understanding is advanced by the combination and balance of views-that is, pinpointing the value added by the integration of disciplines.

The notion above stems from the understanding that no single characterization of "levels of integration" can discriminate between accomplished and novice interdisciplinary work. Instead, Boix Mansilla in 2007 proposed that the success of an integration be measured by the degree to which it achieves its purpose, such as a more comprehensive account, a new legal amendment, an empirically grounded argument, a more generalizable model. In these contexts, the essential question to assess interdisciplinary work is not "How much integration is enough?" but "What is the cognitive and practical purpose of this work, and is this integration advancing it in disciplinary grounded and reflective ways? As a build-up, the integration of disciplinary perspectives is better viewed as a means to a purpose, not an end in itself, and multiple possible integrations are viable. The merit of an integration is to be assessed against the very purpose of each interdisciplinary enterprise. This aligns with using the CARERC core syllabi to develop the rubric as it should exactly measure the extent of achievement of program goals. Consequently, no standard metric applies to work produced for a variety of aims. Instead, a dynamic framework is needed, one that calls attention to the purpose of a particular piece of work as a benchmark by which to judge its successes and limitations (Tripp & Shortlidge, 2020). This thus suggests that if the extent of integration fulfils or meets the purpose of a piece of work, it could then be termed interdisciplinary and completely agrees with the contextual, collaborating and integrating requirements. Examples of competency domains that would easily define this theme would be creative thinking, critical awareness and thinking, integrative and applied learning, ethical reasoning, inquiry and analysis, problem solving, etc. This theme has since seen modification to integration in the IDSR (Tripp & Shortlidge, 2019).

2.3.3 Communication and Translation across Disciplinary Boundaries.

Though integration may by nature be disputable, the same cannot be said of communication across disciplinary boundaries which clearly highlight separate but overlapping disciplines and unequivocally address interpersonal interactions. Most authors agree that collaboration defines interdisciplinarity. Also, Repko's (2008) exhaustive list of attitudes and skills includes references to collaboration and communication with others, but his description of interdisciplinary processes tends to deemphasize collaborative processes. Clearly, those able to create a climate that stimulates dialogue within the group have a greater chance of success" (p. 407). Lattuca and his colleague were quick to point out the fact that "successful interdisciplinary teams invest considerable time in managing differences and creating common ground" (Lattuca et al., 2009). Repko (2008) quotes others who state that common ground is "essential" and "fundamental" to interdisciplinary research (pp. 275–276). Oberg (2009) observes and implies that the common ground being sought is agreement on what constitutes quality demarcation, and areas to consider include literature, methodology, analysis methods, reliability, reflexivity, and standards for presentation of the results. Olson & Olson (2000) observed that “joint construction of common ground can be an especially taxing form of interaction, especially when people appear to be similar but have important hidden dissimilarities” (p. 158). Meanwhile, language and terminology differences between disciplines are perhaps the most frequently cited barrier to interdisciplinarity (Borrego & Newswander, 2010). This theme has seen various modifications and has given way to collaboration across disciplines (Tripp & Shortlidge, 2019), and broader awareness (Tripp & Shortlidge, 2020) but is now missing in recent themes of interdisciplinary studies. Relevant themes that will easily interpret to this theme include oral or written communications, intercultural knowledge and competence, and ethical reasoning.

2.3.4 Critical Awareness

Critical Awareness sheds light on the degree to which a piece of work exhibits clarity of purpose and offers evidence of reflective self-critique (Boix-Mansilla & Duraising, 2007). It proceeds to ask the underlisted questions: (a) Does a piece of student work show clear goals, framing the issue in ways that invite an interdisciplinary approach? (b) Does the work exhibit reflectiveness about the choices, opportunities, compromises, and limitations that characterize interdisciplinary work and about the limitations of the work as a whole, like what an account failed to explain or what a solution could not address? Producing interdisciplinary work of quality demands that students engage in a process of considered judgment, weighing options and making compromises to achieve their proposed aims. The demands of "critical awareness require, for example, that students develop a sense of their work at a meta-disciplinary level, that they identify disciplinary blind spots, consider opportunities for integration, navigate methodological differences, and choose among competing units of analysis. As suggested earlier, the success of integrative efforts must be measured against the goals guiding the enterprise holistically, and faculty valued work that exhibited clarity of purpose (Boix-Mansilla & Duraising, 2007). In addition, this questioning attitude helps to facilitate "framing problems in ways that invite interdisciplinary approaches and exhibiting awareness of distinct disciplinary contributions, how the overall integration 'works,' and the limitations of the integration" (Borrego & Newswander, 2010). In studying whether a pre-existing social science rubric (Boix Mansilla et al., 2009), developed to score student essays related to interdisciplinary understanding in the humanities, could effectively measure the ability of natural and physical science students to communicate interdisciplinary science understanding (Tripp et al., 2020), they submitted that convergent validity could only be established for only disciplinary grounding, while the remaining constructs, integration and critical awareness, failed validity tests (Tripp et al., 2020). Following this conclusion, the rubric was reworked to a new, evidence-based rubric for natural science students, the IDSR in which critical awareness as a theme was clearly absent. However, this conclusion cannot be generalized as it is strictly dependent on the instrument used in the study. "An added benefit of critical awareness as a mode of analysis is its perspective on holistic thinking—looking at the bigger picture, valuing outside perspectives, and enlarging possible horizons of knowledge" (Ivanitskaya et al., 2002; Repko, 2008). Possible themes that further define this are critical awareness and thinking, inquiry and analysis, intercultural knowledge and competence, creative thinking, etc.

2.3.5 Disciplinary humility

Every venture at attempting to commence work across disciplines must begin with "developing a mindset, or epistemic perspective, that is infused with humility, inclusivity, and respect for other disciplinary epistemologies" (Tripp & Shortlidge, 2019). This is considered "prerequisite to and basis for transdisciplinary conversations and transcendent knowledge generation" (Byrne et al., 2016, p. 14). The phrase "disciplinary humility" was adapted and applied to interdisciplinary understanding, and requires reflexivity about one's limitations in knowledge, skill, and awareness of personal biases (NRC, 2015). "To ensure respectful evaluation of similarities and differences of discipline and persons, all metacognitive efforts should begin by infusing disciplinary humility into learners' mindsets at the inception of interdisciplinary thinking, research, and collaborations, making them realize how interconnected disciplines must be in order to solve complex human problems". (NRC, 2003, 2009; AAAS, 2011; Bammer, 2013). Other themes that could define this are critical thinking, intercultural knowledge and competence, oral communication etc. This theme has also seen various modifications and is now missing as a theme in recent interdisciplinary studies.

2.4 Misconceptions around Interdisciplinary terminologies

The literature on interdisciplinary studies has presented the field with various taxonomies of interdisciplinary studies. Descriptors such as (but not limited to) "multi-," "inter-," or "transdisciplinary" (Klein & Newell, 1998; Lattuca, 2001; Newell 2001, 2002) have been used to characterize levels of integration in response to the question, "How interdisciplinary is a particular piece of work?". Table 2.5 below by Blom et al. (2020) clarifies in clear terms the confusions around the use of the terminologies about integration across disciplines: This study will limit itself to degree of integrations that offers solution to complex problems within the interdisciplinary dimension as explained herein. Table 2.5 below shows the competency expectations of individuals and groups regarding each of the misconceived terminologies. This clearly presents the distinction between the different terminologies and compares the expectations of each as against that of interdisciplinarity.

Table 2.5 Hierarchical taxonomy of forms of inquiry (Blom et al., 2020)

FORM OF	COMPETENCIES OF INDIVIDUALS	COMPETENCIES OF GROUPS
Disciplinary	Requisite level of cognitive development: *Highly elaborate abstract mappings.* Individuals demonstrate understanding of a specific set of characteristics of conceptions and one methodological approach. They are able to generate unique questions and contribute new research and findings in this area.	Group is able to produce new knowledge (or confirm existing knowledge) in a specific discipline by employing that discipline's set of concepts and methodologies.
Multidisciplinary	Requisite level of cognitive development: *Abstract systems.* Individuals demonstrate disciplinary competence and understand that their endeavors must be related to the endeavors of others in surrounding disciplines. They therefore come to know and use some concepts used in these disciplines.	Group is able to demonstrate disciplinary competence and relate the results produced by surrounding disciplines to its own, and relate its own results to others (e.g., communication between disciplines).
Cross-disciplinary	Requisite level of cognitive development: *Highly elaborate abstract systems*. Individuals demonstrate disciplinary competence and know how concepts and methodologies from other disciplines relate to their own, having mastered some concepts therein. They are able to constructively communicate with individuals from other disciplines in a problem-focused manner.	Group is able to demonstrate disciplinary competence and to constructively collaborate with groups from other disciplines in a problem-focused manner.
Interdisciplinary	Requisite level of cognitive development: *Multiple principles.* Individuals demonstrate competencies in at least two disciplines. One is primary, yet they are able to employ the concepts and methodologies of another discipline well enough to employ the questions and findings therein. New understanding of the primary discipline result.	Group subsumes at least two disciplinary subgroups, with one as primary focus of expertise. Capable of solving problems that cannot be addressed by either discipline alone, typically in a problem-focused manner.
Transdisciplinary	Requisite level of cognitive development: *Beyond single principles.* Individuals demonstrate at least two disciplinary competencies neither of which is primary. They work and contribute to both and generate unique findings, conceptions, and artefacts as a result of an emergent transdisciplinary perspective. They are able to communicate with individuals from a variety of disciplines in a synoptic manner.	Group subsumes at least two disciplinary subgroups, neither of which is primary. Produces both problem-focused and synoptic knowledge, which cannot be reduced to either of the subgroup competencies. Capable of spawning new disciplines and reforming existing ones in light of newly emergent perspectives.

2.5 Occupational Health and Safety (OSH)

The field of Occupational Health and Safety (OSH) is by its very nature multi- and interdisciplinary because it is first and foremost a field of study in which a multitude of researchers from diverse disciplines converge and several different disciplines are harnessed for its work. It has an entrenched tradition of partnership. Also, the field displays social issues and challenges requiring resolution, with areas of specific concern requiring collaboration (Lortie et al., 2013). Meanwhile, there remains areas of exploration and explicability about the nature of interdisciplinarity and implications of the field (Pink et al., 2019). The disciplines recognized in occupational and safety health are diverse and as follows: Safety and health professionals, Occupational medicine physicians, Wellness program managers, Occupational health nurses, Mining Engineers, Agricultural Specialists, Wellness program vendors and consultants, Industrial hygienists Fitness specialists, health and wellness coaches, Ergonomists, Employee assistance program professionals, Safety program managers, Military public health and medical workforce, Safety engineers and professionals, Primary care providers, Occupational epidemiologists, Community health nurses, Environmental health science directors, Workplace health educators, Organizational psychologists, Substance use professionals, Occupational health psychologists, Sustainability directors, Union representatives, Non-safety and health professionals. Each of the listed fields are such that no single discipline can effectively train individuals to assume proficiency which therefore emphasizes the interdisciplinary need.

2.5.1 Interdisciplinarity in OSH

There have been calls to increase exposure to interdisciplinary science specifically at the undergraduate level by both stakeholders and funding agencies (NRC, 2003, 2009; American Association for the Advancement of Science (AAAS, 2011). The call became necessary because future scientists must be trained to think and work with interdisciplinary mindsets that real world complex challenges require. One prominent recommendation for interdisciplinary science in undergraduate education is Vision and Change in Undergraduate Biology Education: A Call for Action (AAAS, 2011). The report identifies that undergraduate biology students should understand the interdisciplinary nature of science, its role in society, and the ability to communicate two constructs; disciplinary grounding and integration that forms the core of any interdisciplinary work.

Though occupational health and safety is accepted as an interdisciplinary profession, relevant competencies to the field have only recently been identified from emerging literature for the specific disciplines involved. Also imperative to this would be viable means of assessing the identified competencies (Olson et al, 2005). A set of core competencies for preventive medicine and its related specialty areas, including occupational medicine, was first presented by the American College of Preventive Medicine (ACPM) (Lane and ross, 1994; Lane et al., 1995), the list was later updated in 1999 for curriculum development and medical resident evaluation purposes. By 1998, the American College of Occupational and Environmental Medicine (ACOEM) approved a set of competencies, which they described as a "spectrum of competencies ranging from those of the general practitioner (in occupational medicine) to those of a highly trained specialist". ACOEM (1998) prior to this had rejected the notion of a set of "core" competencies and instead promoted the idea of a "menu" of competencies more compatible with the diversity of occupational medicine practice in the United States.

Other initial efforts in the United States include the study conducted by American Association of Occupational Health Nurses (AAOHN) in 1995. An expert committee was saddled with a goal to "identify the issues that stimulated research on competencies and credentialing in occupational health nursing" (Chamberlin and Rogers, 1997). In 1997, a second committee was requested to draft a set of competencies, which was later finalized using external review. In the study, competencies were conceptualized as "things nurses do and are measurable by performance". Like the earlier ACPM guidelines, they proposed a "core set of competencies expected of all occupational health nurses". Also following the ACOEM guidelines, some competencies are expected of only certain practitioners; however, these were delineated by experience as "expert" and "proficient" versus "competent", and not only by subject matter or practice setting (White et al, 1999). The emerging list of competencies was intended as a resource with a variety of purposes: self-assessment, curriculum development, accreditation of training programs, certification of practicing nurses, and evaluation of job performance. Also, the historic report "The Future of Public Health" by the Institute of Medicine (IOM) in 1988 came with a revolution that began the delivery of competency-based crosscutting curricula in the public health communities of practice and academia (IOM, 1998). Also, Accreditation Board for Engineering and Technology (ABET) in year 2000 developed a set of competencies for the master's-level industrial hygiene students, using an outcome-based-criteria to evaluate the programs in industrial hygiene (Olson et al, 2005). A common trend in the above is that "disciplinary approaches are often seen to fail to offer palpable solutions to applied research problems, raising high hopes for interdisciplinary research" as Barry et al (2008: 40) observed and concluded that such "may possibly bring science and technology closer to the needs and concerns of citizens and consumers, reducing the risks of public resistance, uninformed criticism or indifference and stoking the engines of innovation". In a survey designed to assess the value of, and proficiency in some sets of crosscutting competencies by graduates of the program based on their postgraduation job experience, a menu of 29 crosscutting competencies were rated as valuable or very valuable by respondents in each of the four programs surveyed. There was less agreement between respondents in proficiency ratings, with 24 of 29 competencies rated either proficient or very proficient. The authors therefore proposed this set of crosscutting competencies be considered with further testing for adoption as a set of interdisciplinary core competencies for Occupational Health and Safety professionals (Olson et al., 2005).

2.6 Diverse definition of competencies

Modern educational goals and qualifications relevant to current industry need can no longer be portrayed by a fixed set of specialized and transferable skills ongoing between generations. "Rather, nowadays, knowledge must be applicable to different, new, and complex situations and contexts". It is against this background that the concept of competence has attracted increased research attention. Competencies are the skills, knowledge and attitude necessary to be able to solve specific problems under certain circumstances (Friesen & Anderson, 2004; Sampson & Fytros, 2008; El Asame & Wakrim, 2018). Competence is a concept that has not had a consensus definition, compositions, and methodologies among researchers (Cooper, 2000; Dalton, 1997) which makes it prone to confusion and misunderstandings (Byham & Moyer, 2000; Cooper, 2000; Mirabile, 1997). Worse still are the vague, broad and inferred definitions provided by standard dictionaries (Cooper, 2000; Dalton, 1997).

Several studies and efforts had attempted to come up with an acceptable definition for competency, and a comfortable point to begin would be the origin of the word from Latin "competentia" which means "authorized to judge as well as has the right to speak" (Caupin, 2006: 9). McClelland (1973) study defined competence as "a personal trait or set of habits that leads to more effective or superior job performance" in other words, it is a value-adding ability of a person. He concluded from empirical data that profiling the exact competencies required to perform a given job effectively and measuring them using a variety of tests is a better predictor of job success. Closely related to the above is Klemp (1980) who sees the personal trait in McClelland's as "an underlying characteristic of a person". Boyatzis (1982, 2007) adopted the term competency as an "underlying characteristic of an individual that is causal (change in one variable cause change in another) and related to superior performance in a job". He further identified 19 generic competencies that outstanding managers should have and classified the 19 generic management competencies into five distinct clusters, as goal and action management, leadership, human resource management, directing subordinates and focus on others. Page and Wilson (1994) following a review of 337 citations in competencies, defined it as "the skills, abilities, and personal characteristics required by an „effective‟ or „good manager", ACOEM (2021) refers to the above characteristics as physical, intellectual, and behavioral qualifications. Germain to this definition is the mention of easily measurable competencies like knowledge and skills, and the less assessable competencies related to personal characteristics or personal competencies. Gilbert (1996) removed the possibility of coincidence and chance around competence by his definition as the state of being competent which refers to having the ability to consistently produce the results (the worthy outcomes of behavior) that are required for the most efficient and effective achievement of the larger organizational goals. Most definitions of competency are linked with effective performance on specific job requirements as highlighted earlier (Hornby & Thomas, 1989; Jacobs,1989; Hogg, 1989; Evarts, 1998; Woodall & Winstanley,1998; ACOEM, 2021) and a good summary would be Guthrie (2009) who viewed it as “an individual’s professional repertoire which influences the kinds of problems a person can solve”. A few other definitions extended the understanding and pointed out the error of limitation around viewing competencies as mere performance requirements. Koeppen et al’s (2008) definition raised the contextual specificities (also Rothwell et al., 2004) and training requirement through work/life experience and study/training (also Spencer & Spencer, 1993) that usually accompany real life events while Kutz (1994) introduced organized hierarchy and prototypical patterns of behavior that evolve with the view of solving problems into the discourse. Hogg (1989) extended his view to the transferability of skills and abilities from one area to another. Dubois (1998) added a continuum that expresses competency based on the variety and proportion of skills and abilities that constitute it. Cernusca and Dima (2007) emphasized the need for competency mapping and the possible appraisal tools {Gasper (2012) used “performance management competency”}to help reduce work and role mismatches.

Many of the definitions above agree to a collection of success factors necessary for succeeding in specific tasks. Success factors usually consist of knowledge, skills, and abilities

(KSA). A seemingly more instructive and detailed perspective is the "Iceberg Model of Competency" (Spencer & Spencer, 1993) which:

> "Conceptualizes five types of competency characteristics: 1) motive; 2) traits; 3) social role and self-concept; 4) knowledge; and 5) skills. Knowledge and skill components tend to be visible, measurable and can easily be developed through training. Meanwhile, social role, self-concept, trait, and motive competencies are more hidden, and they represent a person's central personality (the metaphorical submerged part of an iceberg)".

The authors added the causal relationship between the underlying characteristic of a person and the achievement of effective or better work performances.

From the foregoing and summarily, "*competencies are specific qualities that individuals acquire by training and practice, observable in particular contexts with the capability to consistently apply or use a continuum of knowledge, skills, abilities (KSA) (Campbell et al., 1993, p. 40) to successfully perform critical work tasks (Guthrie, 2009). These qualities when possessed and specifically deployed to effectively execute an interdisciplinary assignment would be tagged interdisciplinary competency"* and would be the context of this study.

2.7 Interdisciplinary Competency in OSH

By combining the outcomes of the different literature to successfully formulate a viable interdisciplinary competent work definition, key considerations are as presented in Table 2.6. Summarily, the Components that will adequately define interdisciplinary work would be contextual, collaborative, integrating, span continuum, purposeful, exploit personal traits and application of knowledge and understanding. This study intends to conceptualize its definition to adequately capture these identified perspectives and present a competency-focused measure of interdisciplinary engagement in Occupational Safety and Health in the CARERC program.

Table 2.6 Key considerations to successfully formulate a viable interdisciplinary competent work definition.

S/N	Theme	Interdisciplinary competency in OSH	Source
1	Existence of a continuum of collaboration where interaction may range	Possibility of different modes of interdisciplinary research quality	Boix Mansilla et al., 2007; OECD, 1998;
2		Simple communication of ideas to the mutual integration of organizing concepts	Boix Mansilla et al., 2009; Tripp & Shortlidge, 2019; Tripp & Shortlidge, 2020; Tripp et al., 2020
3	Definition and fidelity to disciplinarity	Thought domains	Aram 2004
		Specific body of teachable knowledge	Woollcott 1979
		Conceptual specificity	Robertson et al., 2003
		Journal sets	Morillo et al., 2003
4	By social factors	Isolated domains of human experience possessing its own community of experts"	Nissani 1997
		Self-regulating and self-sustaining communities	Lattuca 2002
		Degree of communication and sharing {existence of a continuum from multidisciplinary to interdisciplinary was apparent	Tripp & Shortlidge, 2019; Tripp & Shortlidge, 2020
5	Outcome of the collaboration	Could be product or process (social scientist's perspective	Aboelela et al., 2007
		Apply or use varied proportion of knowledge, skills, abilities (KSA), behaviors, and personal characteristics to successfully perform critical work tasks, specific functions, or operate in each role or position	Campbell et al., 1993., p. 40, Gilbert, 1996; Friesen & Anderson, 2004; Sampson & Fytros, 2008; Guthrie, 2009., El Asame & Wakrim, 2018; Claus & Wiese, 2019

Consequently, this study is proposing interdisciplinary competencies in OSH that are focused on the ability to apply the integrated knowledge, skills, and capabilities consistently and effectively as a result of the successful collaboration between more than one OSH disciplines to promote diversity in the field. A robust definition of interdisciplinary competence in OSH would require graduates of CARERC program to:

> "*Be able to successfully apply critical work tasks, specific functions, or operate in a specified OSH role or position to demonstrate cognitive advancement due to their acquired capability to consistently apply, use or integrate knowledge, skills, abilities (KSA), behaviors, and personal characteristics effectively as afforded by collaborative merger of more than one disciplinary lens of OSH disciplines".*

They should demonstrate the skill to integrate knowledge and modes of thinking from two or more disciplines which results in a cognitive advancement, such as the explanation of a phenomenon, solving a problem or producing a product, which would not have been possible if solely the knowledge of one discipline had been used. Expected interdisciplinary competencies are listed below:

> *"Skills and capabilities to identify, assess, and control occupational and environmental hazards that may adversely affect the health of communities and working populations, recognizing hazards and evaluating control measures to reduce occupational health and safety risks across a wide spectrum of industry sectors, successfully recognize and assess the hazards associated)"*

2.7.1 *Desired Competencies in Interdisciplinary OSH*

In line with ACOEM guidelines (1998), the desired competencies for occupational and environmental medicine (OEM) will require “a menu of defined and demonstrated subject matter expertise (demonstrated proficiency) in at least one of the relevant disciplines plus cross-cutting skills including a basic understanding of, and experience in, data collection methods, research design, and data analysis methods related to the individual’s primary profession and adapted to broader workplace safety and health issues”. This set of competencies also includes the application of risk assessment and analytics to strategic decision-making and should have the ability to effectively design, implement, and evaluate programs, policies, and procedures by applying best practices to optimize adoption and sustainability. This set of OEM competencies was later updated in 2008, and again in 2014. Recent advances in US OEM residency programs required some update to these OEM competencies to stay current with the field and practice of OEM. Thus, Physicians practicing OEM are expected to “understand how to recognize, prevent, evaluate, diagnose, treat, and manage adverse health effects from workplace and environmental hazards, as well as, how to create and promote a culture of wellness in the workplace” (ACOEM, 2020).

In addition, an invited roundtable in November 2017 at the University of North Carolina at Chapel Hill brought together representatives from NIOSH, its six funded Total Worker Health (TWH) Centers of Excellence, NIOSH-Funded OSH training programs and all stakeholders. During the roundtable, workforce training needs and approaches were explored, and one of the four main tasks identified was to create competencies for Total Worker Health (TWH), an expanded focus for occupational safety and health (OSH) (Newman et al., 2020). The TWH as the most recent study in the area of OSH, also proposed a set of core and cross-cutting competencies to be used across OSH programs following a 5-year study involving key stakeholders regarding education and training needs. A few of the core competencies compiled for the TWH (Newman et al., 2020) are found embedded already in different proportions in the competencies fronted in this study. The TWH program, however, is beyond the scope of this study.

Adherence to the guidelines above is clearly evident in the competencies outlined in the core syllabi of the CARERC program to be used in this study and other ERC programs. Olson et al. (2005) in their paper confirmed that most program-eligibility requirements for ERCs stated that trainees must be "exposed to the principles of all other occupational safety and health core and allied disciplines" and centers "must give special, innovative, attention to thoroughly describing the approach for fulfilling interdisciplinary interaction among students".

2.7.2 Challenges of Interdisciplinary competencies

The construct of competencies calls for performance data about outcome measures (Carol & Wiese, 2019). These measures must be based on empirical foundations. Unfortunately, the major challenge around interdisciplinary competencies had been that of consensus definition and adequate conceptualization, what to assess to adequately confirm interdisciplinary competence and how to assess it (Tripp & Shortlidge, 2020; Boix Mansilla et al., 2009; Balgopal et al., 2012;

Lattuca et al., 2012). This study employed literature to resolve these identified challenges around interdisciplinary competency in OSH.

2.8 Interdisciplinary Competency Evaluation Rubric in Occupational Safety and Health (iCER-OSH)

In a survey asking teachers and instructors via an online survey about how they assess interdisciplinary competencies and students' interdisciplinary understanding, as well as how they define "interdisciplinary science". Tripp & Shortlidge (2020) observed that writing assignments were mostly used to assess interdisciplinary competencies. Writing assignments simultaneously require students to explicitly identify contrasts between disciplines and criticize their own understanding (Boix Mansilla et al., 2009; Balgopal et al., 2012). Other methods mentioned were traditional exams or quizzes and group work. Based on the above, the authors constructed a writing assignment where students must use their interdisciplinary understanding. These authors proceeded to assess the written assignments based on their findings from their first study using an adapted version of the Boix Mansilla et al. (2009) pre-existing rubric. Clearly emerging from the exercise was that "students needed more guidance on how to conceptualize interdisciplinary connections". A shortened version of the rubric, which contained guiding questions, was later administered to the students.

To confirm the efficiency of the rubric, multiple semi-structured interviews were conducted with some of the students to explore whether the rubric score matched students' verbal understanding of interdisciplinary science. Obvious discrepancies were observed between the interviews and essay scores, as more than half of the students showed integration knowledge and critical awareness constructs in their interviews but not in their essays. The authors concluded from the findings above that the rubric did not fully capture students' interdisciplinary understanding and proposed that a framework might be more suitable for interdisciplinary assessment.

2.9 Assessment of Competencies and Interdisciplinary competencies

Carol and Weiss (2019) with Brandstädter and Sonntag (2016) present "interdisciplinary competencies as instrumental sets of behavior in dealing successfully with interdisciplinary endeavors", indicating that "interdisciplinary competencies extend teamwork competencies to the specific demands of interdisciplinary work settings" (Stevens & Campion, 1994; Bromme, 2000). This suggests the specific requirement of competencies in determining either the success or failure of interdisciplinary endeavor. Sandberg (2000) mooted that this specificity of interdisciplinary competencies follows an interpretative approach that puts weight on how the employee perceived it and their experience (Carol & Wiese, 2019). In short, interdisciplinary competencies are learned instrumental behaviors, which enable employees to deal with the specifics of working across disciplinary boarders. As much as teamwork competencies are required in interdisciplinary work, the requirements extend beyond them (Stevens & Campion, 1994), to include an integrative core.

Competencies should not only be defined and practiced through appropriate assignments during a course or curriculum, but they should also be assessed effectively (Blom et al., 2021). Also, the construct of competencies calls for performance data about outcome measures (Carol & Wiese, 2019). To date, a generalized assessment method for interdisciplinary assignments, courses and/or programs has not yet been developed. This is partly due to the lack of empirical research into interdisciplinary assessment methods (Boix Mansilla et al., 2009; Tripp & Shortlidge, 2020), and to the absence of a cognitive model of interdisciplinary understanding (Boix Mansilla, 2005). This study is filling the above gaps by building on available literature to conceptualize interdisciplinary competency in OSH and aligning a framework on which a rubric would be developed.

Assessment usually takes place in the context of learning goals and objectives, which are used to design specific assignments aimed at developing the competencies mentioned therein. To establish a common practice for interdisciplinary assessment, it would be useful to agree upon a common set of learning goals (Dainty et al., 2003). Therefore, it is useful to start with an overview of the learning goals and objectives that are most often mentioned regarding interdisciplinary education in literature. Learning goals and objectives in this study was based on evidence set forth from previously published studies. Although a wide variety of learning goals and objectives have been described in the literature of interdisciplinary higher education, many of them were found overlapping rather than complementary, or merely phrased slightly differently, rather than making a crucial distinction (Boix Mansilla et al., 2009). This study had earlier presented what is viewed as the four main learning goals in interdisciplinary education (disciplinary grounding, perspective taking, finding common ground, and integration), as interpreted via program learning goals, course learning outcomes, and the empirical studies, together with a short explanation of the main competencies (skills, knowledge and/or attitudes) a student should exhibit upon achieving these learning goals. This was clearly reflected in the iCER-OSH framework in the later chapter.

2.10 Challenges of Assessing Interdisciplinary Competencies

As earlier stated, assessing interdisciplinary competencies has been challenged by the problems of adequately conceptualizing the construct in order to easily itemize what to measure and later how to measure it. The iCER-OSH framework should resolve the above challenge in this study.

2.11 Principle of Constructive Alignment

Developing the iCER-OSH rubric was premised on the principle of constructive alignment, which is based on Thomas Shuell's (1986) summary of cognitive psychology regarding teaching and learning which states that the extent of student's engagement with learning mostly determine how and what they learn; what their construct of concepts is than how and what the teacher does. The transparency that the rubric presents for outcomes, method and assessment becomes the bedrock for designing effective teaching programs that easily influences how students construct their own learning and engagement activities. Constructive alignment "is a form of outcomes-based teaching and learning in which both teaching, and assessment are aligned to the Intended Learning Outcomes (ILOs), which specify what the student is expected to do with the content taught" (Biggs, 1996; Biggs & Tang, 2011). Constructive alignment originates from the theory of constructivism which rests on observation and empirical evidence of how people learn. Furthermore, it suggests that "learners actively construct their own knowledge and understanding". The constructivist hypothesis puts substantial emphasis on meaning, reflection and context, and teaching around what the context is and "this provision allows the facilitation of desirable learning outcomes in Higher Education" (Ali, 2018). In simplified terms, rather than transmitting a body of knowledge, constructivists would construct meaning based on interactions with the learning environment.

Fundamentally, the constructive alignment theory is founded on:

1. a framework of curriculum design in which intended learning outcomes, teaching methods, assessment and evaluation are all interdependent and only by truly integrating these components together, do we get efficient student learning as is being proposed by this study.
2. staff involved in teaching must develop a "reflective practitioner" approach to their work and be prepared to learn from their mistakes and successes. This would be made easier by a guiding rubric.
3. Meaning is not imposed or transmitted by only direct instruction; it is created by the student's own learning activities (Biggs, 1999b). In this case, a transparent capstone experience is based on clear interaction between learning outcomes, methods, and assessment.

According to Biggs (1999) "the fundamental principle of constructive alignment is that a good teaching system aligns teaching method and assessment to the learning activities stated in the objectives so that all aspects of this system are in accord in supporting appropriate student learning". In the above context Biggs argues for a curriculum which can make sure the aims of the program ILOs, the teaching methods and assessment strategies are aligned and consider all relevant factors. Such results as argued by Biggs can be achieved by this study.

Outcomes-based teaching and learning, which addresses the learning outcomes that students are expected to achieve at both program and especially course levels could be comparable to the contents presented by literature indicating what goes into preparing students for the capstone and eventually professional competence. Once the outcomes have been defined, teaching should be designed to engage students in learning activities that are likely to achieve those outcomes. Assessment then addresses how well those outcomes have been achieved by students and is therefore criterion referenced. Such assessment is best achieved by rubrics or statements that specify the standards for different levels of student performance (Biggs & Tangs, 2015). Assessment tasks should also allow for any unexpected or unintended but desirable outcomes. Constructive alignment referred to in this study includes among other things outlined by different authors students being able to focus more effectively on the key learning goals, fairer and more reliable assessment, improved learning outcomes, including critical thinking and depth of student work, increased transparency leading to easier and more accurate interuniversity and international comparisons and greater coherence in programs and more effective evaluation of modules and courses.

The major criticism of constructive alignment refers to staff and student workloads. The major staff workload is in the initial transition from traditional to constructively aligned teaching, while that for students is often self-inflicted as they commit more work and time to constructively aligned courses. Also, this seems to give some power and more responsibility of learning on the student's shoulder.

2.11.1 Constructivism and Intended Learning Outcomes

Ideally, curriculum should be designed in such a way that the learning activities and assessment tasks are aligned with the ILOs, what the students should be able to do or demonstrate. This suggests that teachers must have a clear idea of what students intend to learn and be able to do at the end of their module/unit. In addition, learning outcomes should be communicated to students at the start of the course where the responsibility of achieving the ILOs is shared since the focus is on student' realization to take full participation in the responsibility of their own learning. The intended learning outcome would then be verifiable by the assessment tasks (Ali, 2018). An important feature of constructive alignment is to make well-informed and knowledgeable decisions about which teaching and learning approach would be most significant to permit student to move towards achieving the learning outcomes and demonstrating that achievement in suitable framework like the iCER-OSH. Furthermore, as Ali (2018) alluded "constructive alignment is about ensuring that assessment, teaching, learning and feedback should be in synchronous with each other, and that feedback links well to students' evidence of demonstrating their achievement of the intended learning outcomes". The above principle will inform the design of the descriptors in the developed rubric and assist in conceptualizing the

Interdisciplinary Competencies that are based on empirical evidence and on the assumption that teaching was done in synchrony.

2.12 Capstone Projects

Capstone projects are tasks that culminate students' knowledge and skill and, in this case, competencies following a period of study. Capstones draw from a range of knowledge from courses in a curriculum, with the intent to give students unique opportunity to conduct in-depth research and propose innovative solutions to specific problems. Typically, it is done in conjunction with a local site in which the student has some involvement, such as a local school or business (Husna, 2009; Jones & Tadros, 2010; Ahmad et al., 2011; Stanford et al., 2013) and in the case of this study an industry, farm, or mining site.

The field of capstone projects as culminating experience for students in undergraduate education has been impacted by two major studies; Reinventing Undergraduate Education: A Blueprint for America's Research Universities, by the Boyer Commission on Educating Undergraduates in the Research University (1998), and The Senior Year Experience: Facilitating Integration, Reflection, Closure, and Transition, by John Gardner and Gretchen Van der Veer (1998b). While the Boyer Commission report set the tone for the conversation about the key attributes of the capstone experience, "The Senior Year Experience" sets the tone for the conversation about the role of the capstone experience in the transition of seniors from college to "life beyond college" (Levine, 1998, p. 58) and helps define the importance and role of the capstone in the senior experience. As early as 1998, the Boyer Commission in their report recommended among others that capstone projects “should be collaborative and team-based to prepare students for professional life; scholar-teacher mentors who understand major projects should work with students; each project should serve as a bridge to graduate school or to the workplace; and projects should serve as the culminating experiences in students’ majors”. Several attributes have been added to this list as capstone research progresses since the Boyer Commission report, “including that students should have an opportunity to reflect on their past accomplishments and future possibilities as part of their capstone experience” (Brooks et al., 2004; Olsen et al., 2002; Rowles et al., 2004); “that students should present their research findings” (Rowles et al., 2004; Sullivan & Thomas, 2007); “and that students should apply university-developed academic skills to the solution of specific community issues” (Collier, 2000, p. 294). In short, the capstone strategy course is intended to show students “how everything fits together” and “how to think and make decisions like a senior manager” (Rapert et al., 2004).

Mostly, capstone projects and programs appeared to have been largely influenced by engineering programs, ABET criteria and industry input, nonetheless, it has been applied in many other fields of study beyond engineering (; (Rowles et al., 2004; Husna, 2009). These “projects represent a critical juncture in students' development and help their transition from university education to professional work” (Dutson et al., 1997). Varied design strategies that simultaneously build confidence and identity had been employed to train students through the engineering process to prepare them for workplace and industry experience (Zhang et al., 2022). Capstones are usually supplements to the usual final examination and allow students a practical application of their learning. While challenging, capstones are also rewarding since the extensive knowledge acquired by students during the process boosts students' professional skill and offers opportunities for hands-on experience which is a key component. In the process, learners while exploiting a need-based approach "will identify a process that needs to be changed, design the program or process to initiate the change, and then evaluate the results". Learners are then propelled to think critically and apply learning through the program and provide feedback on what has been learned in the program. It thus assures faculty of a prepared and ready trainee for the workforce (Zhang et al., 2022). "Compared to other examinations or theses, capstone projects are peculiar due to its real-world application. Capstone projects offers students' knowledge application as they would in the future rather than just proving understanding of the subject matter. Summarily, via integrating basic research skills and practical experience, trainees end up showcasing a competitive portfolio to future employers. This is then presented as a final write-up/thesis to the certifying institution" (Roethlein et al., 2021).

Key among emerging trends is the rise in multi- and interdisciplinary projects that require that student design teams are assembled from varied majors and or emphasis areas within a major (Stanford et al., 2013). Closely following this trend is the need for knowledge integration and integrative experience for students that had influenced curriculum designs for authentic engineering model experience (Desjardins et al., 2010; Roethlein et al., 2021). Roethlein et al.'s (2021) study came to the observation above after exploring student interview outcomes and company's returning support. They submitted that "a required capstone course with semester-long empirical projects has provided an integrative experience for students, companies, and faculty, despite evidenced challenges". The observed growth in integration seen in both curriculum design and student experience of capstones have been confirmed a key component of any interdisciplinary work and as such, it infers that capstone projects could be a fitting learning method that could resolve the challenge of assessing interdisciplinary competencies earlier discussed.

While quoting McGill's (2012) "Understanding the capstone experience through the voices of students", Roethlein et al. (2021) reported that "most of the student's learning came from the knowledge they applied and the skills they developed in capstone, while their worth of capstone is based on their sense of achieved accomplishment and the proposed long-term benefit from the experience. While realizing the limitation that the study was exploratory in nature, the findings are not definitive nor generalizable but to capstone programs on other campuses, notwithstanding, the study serves as initial evidence and offered six vital points that are very instructive about capstone projects".

Capstone projects are varied and can be case studies, research papers, surveys, outcome-based evaluation, focus groups, and more. The type and complexity are dependent on the tutor's requirements and course (Husna, 2009). These variations observed in capstones make it challenging to design a one-size fits all rubric for assessing capstone projects. Many capstone projects follow the five-chapter thesis format with varied arrangements. Nonetheless, this study reviewed the capstone projects in their format and evaluated only for "presence' or "not" of the interdisciplinary competencies in the written capstone projects submitted to the CARERC program.

Recently, “capstones have grown in scope, importance, and necessity, as the result of institutions’ heightened sense of accountability for documenting student learning outcomes and their recognition that thoughtful reflection on lessons learned is part of the foundation of lifelong learning. As such, capstone experiences are typically organized around one of two broad emphases in higher education: student development or assessment” (Rowles et al., 2004). Overall, “capstone experiences are typically used to facilitate integration of learning in the major and to connect that learning back to the institution’s general education themes and purposes” (Zhang et al., 2022).

2.12.1 Challenges of Capstone projects

The capstone, though one of the most important courses in any engineering program, due to its dual platform to climax learner’s experience and develop non-technical, but essential skills, it is not without its associated challenges.

First, capstone design experiences continue to be the most difficult course to effectively administer due to their resource intensive nature. Students would therefore desire that some of the required resource burden be shifted from them (McGill, 2012), yet this remains a big challenge in many institutions. A study aimed at determining if students enrolled in a capstone course increased their depth of knowledge in research processes and if they increased efficacy in conducting research over the same period was conducted. A part of the findings indicates a decrease in many areas of efficacy and the need for an additional course supporting their research knowledge prior to the capstone. The work shows that graduate students in service field programs, especially anywhere internationally require support especially those without the resources to ask for the proper support (Adams, 2014). This study thus raised the challenge of specific support for students undertaking a capstone project.

Also, the challenge of developing a common approach to capstones has been raised (Chong & Romky, 2012) but this is usually underscored by the history, structure, and context of the institution considering the diversity of disciplines, programs and students (Rowles et al., 2004). This thus explains the need for program specific assessments as is being emphasized in this study. It would therefore be the recognition of the institutional context in which capstone experiences is organized, that the faculty learning community will identify several assumptions that would guide its efforts (Rowles et al., 2004; Chong & Romky, 2012). Despite the above, the variability of the students' research projects presented significant challenges for common rubric development, thus demanding a rubric that is flexible in its application to varied projects, authentically representative of the learning objectives of the thesis course and capable of facilitating common assessment practices and possible inter-rater reliability across many supervisors who serve as primary assessors (Chong & Romky, 2012).

Also reported (LeRoux & Parmigiani, 2018) is the tendency to sacrifice the technical content for excellence in writing as an unintended consequence of capstone as a writing intensive course. While this should be avoided, the opposite tendency must also be avoided, such that a balance must be struck where excellence in writing and a strong technical background must not be compromised.

The preference for multiple and diverse disciplinary teams working together to conceptualize, design and implement capstone projects is increasing and the literature is resplendent with different studies fronting the benefits and innovations that comes with such tasks (Tajaama et al., 2013; Simpson et al., 2013; Sirinterlikci, 2014; Cooper et al., 2015; Jiji et al., 2015; Ritenour et al., 2020). However, this is not without the sometimes hydra headed challenge of assessing individuals that comprise such teams or assessing the work which is usually a written report and/or whether the written capstone thesis is sufficient to evaluate knowledge, skill or competencies acquired throughout. These issues have stalked both instructors and students in such programs. In an unpublished effort, Rios and Alba-Flores on their website (www.capstonedesigncommunity.org) reports using a peer-review assessment study to resolve the challenge of assessing individuals on a team with a peer review process. The peer review process is performed on two comprehensive written reports and two oral presentations that are submitted by the teams. Equally, Friess & Goupee (2020) proposed a capstone project assessment system that incorporates continuous peer evaluation as a major means of assessing individual contribution to a directly assessed team deliverables using a Participation Factor (PF). Instructor observation was also conducted to support the effectiveness of the peer evaluation process. The major limitation of the paper was that results evaluated over three iterations of the assessment process indicate a weak positive correlation (0.26) of the peer evaluation with the individual instructor-graded deliverables as well as the individual student grade point average (GPA, 0.23). The paper, however, recommends improved communication capabilities within the capstone sequence. Different approaches, both formative and summative, are being employed including consistent end-of-course evaluation with other self-report measures.

Assessment of capstone projects is particularly challenging because it is important to contextualize student learning and present the complex multidimensional projects in an assessable format, since assessment is concerned not just with end results but also with the process of learning. Second, assessment work grows from findings that measuring the impact of service learning on students requires collecting data from multiple sources (Rhodes & Agre-Kippenhan, 2004). As assessment comes to mind, capstones become one of the activities that is used in assessing program-level student learning outcomes. Essentially, capstones seek to answer the central questions: What does the student know? What can the student do? What evidence suggests what students know and can do? Results from capstones are aimed at improving instructional practices, and capstones are frequently used to provide accountability and documentation for a variety of audiences, including employers, accreditation officials, parents, and policy makers (Rowles et al., 2004). The most challenging aspect of this is to formulate an assessment methodology for evaluating the extent to which such a project has groomed the student in terms of Program Outcomes (POs) (Sasipraba et al., 2020). In other words, despite all that the capstone project can reveal in terms of what a student has learned, it is still challenging to design an assessment protocol that would totally capture the extents to which the evidence of learning outcomes could be attributed only to the project. Moreso and especially that the capstone project would not have happened in isolation of other learning experiences and exposure.

Remarkable efforts have been and are being made to resolve the nagging problems of assessment of capstone projects and more so of individual's effort in a capstone project in a team. Accreditation Board for Engineering and Technology (ABET) (Husna, 2009) has promoted and monitored development of capstone project work both to develop and assess individual students and to provide evidence for assessing standards in programs of study. The written work used in this study, however, is exempt from this challenge as all submissions are individual. This study thus developed a rubric that will fairly assess capstone projects executed and submitted to the CARERC program though course attainment assessment for capstone project has not been described in any articles. Suggestions are emerging despite the necessity to evaluate using a good assessment mechanism for capstone projects (Sasipraba et al., 2020).

2.12.2 Assessing the CARERC Capstone Projects

Students' experience with capstone projects have been assessed "using numerous methodologies, including examination of student work" (Berheide, 2007; Mansilla, 2005); analysis of surveys administered to students (Brooks et al., 2004; Collier, 2000; Lockhart & Borland, 2001); examination of course evaluations (Clauss & Hawkins, 2007); examination of student self-reporting in journals, focus groups, or evaluations (Dunlap, 2005; Rhodes & Agre-Kippenhan, 2004); analysis of completed assessment instruments and/or rubrics (Kerrigan & Jhaj, 2007; Oh et al., 2005; Payne et al., 2002); and analysis of student interviews and classroom observations (Boix Mansilla & Duraising, 2007). Many methodologies have been used to examine specific aspects of the capstone experiences of students, such as working with community members (Rhodes & Agre-Kippenhan, 2004), incorporating a service-learning requirement (Kerrigan & Jhaj, 2007), or using capstone as a socialization agent (Collier, 2000) or in the development of self-efficacy (Dunlap, 2005). Efforts have also been made to focus on specific aspects of the student capstone experience within a single department or across a single major. Examples of this include assessing student learning in capstone in sociology (Berheide, 2007), connecting capstone to assessment and accreditation in liberal studies (Clauss & Hawkins, 2007), assessing self-reported learning in a software engineering capstone (Dunlap, 2005), reporting on the replacement of exams with capstone experiences in biomedical sciences (Oh et al., 2005), assessing student learning outcomes in capstone to meet accreditation standards in business (Payne et al., 2002), and documenting student achievement of departmental learning outcomes in psychology (Sullivan & Thomas, 2007). While one study by Kerrigan and Jhaj (2007) does focus on improvement of the student capstone experience, it narrowly examines improvements needed in terms of learning outcomes tied to general education goals. McGill, in 2012 also examines the capstone through the eye of students in a qualitative study that recognizes the limitation that it is only exploratory in nature, the findings are not definitive and cannot be generalized to capstone projects in other campuses.

Reid et al. (2022) assessed research theses with the creation of six task-specific rubrics corresponding to quantitative, qualitative, mixed methods, systematic review/meta-analysis, protocol development and resource development project types (Reid et al., 2022). In another study, "each research thesis was assessed using a generic rubric structured according to the evaluation categories of abstract (10 marks), introduction (15 marks), methodology (10 marks), results (20 marks), discussion (25 marks), conclusion (10 marks) and organization/presentation (10 marks)". Another study was also conducted to meet requested goals of engineering studies, which is to enhance the communication skills of students and higher education in general (Requena-Carrión et al., 2010), considering that the ability to communicate technical concepts in a clear and concise manner will be very important in their careers. The Engineering Criteria (2000) of ABET described this ability as an essential engineering skill.

In 2007, the Association of American Colleges and Universities released its signature report from the National Leadership Council, College Learning for the New Global Century, highlighting "how critical it is for students to prepare for the challenges of the twenty-first century. The report presents, among others, "intellectual and practical skills students should have attained by the time they graduate. The skills identified include the following: inquiry and analysis, critical and creative thinking, written and oral communication, quantitative literacy, information literacy, and teamwork and problem solving" (National Leadership Council, 2007, p. 3).

The critical importance of students accomplishing proficiency in these areas is well documented from the perspective of employers. A 2008 study prepared on behalf of the Association of American Colleges and Universities surveyed more than three hundred employers across the country and found that the three areas of learning most in need of improvement are critical thinking, writing, and self-direction (Peter D. Hart Research Associates, Inc., 2008, p. 3). Focusing on the area of writing alone, “employers pay a very high financial cost because of students entering the workforce unprepared to write as professionals”. In 2004 the National Commission on Writing, established by the College Board, issued a report titled “Writing: A Ticket to Work or a Ticket Out”. For the report, the commission (2004, p. 4) surveyed 120 major corporations across the United States and concludes that companies were spending approximately $3.1 billion annually to remediate writing skills of employees. The report designates writing a “threshold skill” for hiring and promotion among salaried employees and declares that “poorly written job applications are a figurative kiss of death” (National Commission on Writing, 2004, p. 4). This kiss of death carries a particularly high cost for students entering the workforce: they can unknowingly disguise their potential to be excellent employees with poor writing. Students in the study acknowledged that capstone is the course in which they experience significant improvements in their writing skills, as well as in many other skills required for success in the twenty-first-century workforce.

Writing was selected as the best option from the foregoing for assessing capstones and its interdisciplinary thinking for three major reasons suggested by Wolfe, et al. (1999). “First, writing is greatly valued across the curriculum, and particularly in interdisciplinary contexts. Almost all fields and disciplines ask their scholars to conduct original research and to communicate those ideas through writing. Second, writing is generally one of the primary means of assessing learning in every discipline or major. Not only do faculty members across the curriculum assign writing to their students, but it is also a skill that is expected in virtually every professional interdisciplinary setting. Finally, writing produces a fixed, concrete record (i.e., the text) that can be used to assess indirectly more fluid, dynamic, and ephemeral mental processes such as synthesis and integration". Jones and Tadros (2010) assessed capstones theses as a component of overall course assessment which comprise others like oral presentation, timeline and teamwork.

Tripp et al. (2020) in trying to determine the current state of interdisciplinary assessment in science faculties, asked teachers and instructors via an online survey how they assess interdisciplinary competencies and students' interdisciplinary understanding, as well as how they define "interdisciplinary science". The outcome of the survey revealed that writing assignments are mostly used to assess interdisciplinary competencies. Caution must be taken however, because writing assessment is a complex and error-prone cognitive process (de Smet et al., 2012; Erguvan & Dunya, 2021) and can be very subjective. Notwithstanding, writing assignments require students to explicitly identify similarities and differences between disciplines (jargon, methods and methodologies, concepts and ideas), at the same time asking student to be critical of their own understanding (Connolly & Vilardi, 1989; Rivard 1994; Keys, 1999; Boix Mansilla et al., 2009; Balgopal et al., 2012). Considering the above, it could be argued that writing assignments are a good way to test students' interdisciplinary understanding. This would be the first Rubric designed based on assessing interdisciplinary competencies in a written work submitted to a program.

2.13 Conceptual Framework for Assessing Interdisciplinary Competencies in CARERC

The goal of the CARERC program, public knowledge as shared on its website indicates that trainees will be systematically evaluated on their general knowledge of epidemiology as well as specific issues in occupational epidemiology and on the topic associated with their capstone. To successfully complete their research theses, students must demonstrate skills in gathering and analyzing data to address a specific research question, interpreting their results, communicating their research findings, and discussing the implications of their findings in the context of existing research and knowledge (https://www.uky.edu/erc/occupational-epidemiology/curriculum). The above is in consonance with the requirement in Reid et al. (2022) which requires that for participants to successfully complete their research theses, students must demonstrate skills in gathering and analyzing data to address a specific research question, interpreting their results, communicating their research findings, and discussing the implications of their findings in the context of existing research and knowledge. Successful completion of the subject overall also involves satisfactory completion of a literature review, progress reports, a conference poster and an overall supervisor evaluation (Reid et al., 2022). For most of the capstone reports submitted and present on the virtual repository, only what is captured can be evaluated which may impact on how the outcome is perceived.

A fair and valid assessment of the capstone projects of the students would not only meet previous needs but would also sufficiently justify the purpose of the CARERC program and resolve a part of the capstone challenge. In furthering the discussion, this study developed an assessment rubric and evaluation framework for the CARERC capstone design that is both easily understood and implemented by students and faculty alike. This would be designed to achieve the following goals: clear communication of standards, fair evaluations of very different solutions, clear communication of outcomes, and encouragement of follow-up/corrective work.

Finally, the variety of student's background, orientation and exposure formed the basis for activities that occur in capstone experiences and the ultimate framework for assessment.

2.14 Psychometric construction of metric instrument

Valid test construct forms the basis for the grader's decision and what the quality of learning outcomes is, and assessment is operationalized on such validity. Thus, a valid and effective assessment rubric for evaluating the quality of learning outcomes becomes essential to a successful education (Qomaria & Thahara, 2015) since "the quality of assessment techniques has always been complimentary to effective learning" (Khorami & Modarresi, 2019). The present study, aimed at developing and validating a rubric for interdisciplinary competencies, is therefore in the right direction for the CARERC program. The first step in this scale construction was to arrive at an operational definition of the construct in question (Gregory, 2004).

Based on literature and the core syllabus of the CARERC program, the designed definition of interdisciplinary competencies was checked for construct validity with the dissertation committee. The approved definition of the developed iCER-OSH framework and matrix was used to construct a dichotomous rubric. The initial iCER-OSH rubric was subjected to the Rasch rating scale model for dichotomous data to investigate its psychometric properties focusing on dimensionality, reliability and the appropriateness of the scoring rubrics to ensure that the item of the developed rubric fits the Rasch model. The psychometric process involved constructing of the rubric and validating the developed rubric.

2.14.1 Rubrics

Tools anchored on behavioral constructs are best used to take a qualitative/quantitative look at performances for teachers to define specific performance levels. Such tools present clear outcomes that point learners to specific targets of achievement. Tools like the above are called "Rubrics". In Panadero and Jonsson's (2020) definition, "Rubrics are instruments designed to assist assessors in judging the quality of student performance and/or help teachers and learners to judge the quality and progression of student performance". Huba and Freed (2000) in their definition present the rubric as

> "A type of matrix with scaled levels of achievement or understanding for a set of criteria or components of quality for a given type of performance, for example, a paper, an oral presentation, or use of teamwork skills. In this type of rubric, the scaled levels of achievement (gradations of quality) are indexed to a desired or appropriate standard (e.g., to the performance of an expert or to the highest level of accomplishment evidenced by a particular cohort of students). The descriptions of the possible levels of attainment for each of the criteria or components of performance are clear enough to make useful for judgment of, or reflection on, progress toward valued objectives" (Huba & Freed, 2000).

Clearly defined levels of performance that infer varying degrees of successes founded on teacher's criteria are the major characteristic of a rubric. The rubric's key strength lies in its ease of viewing student's performance, strength and patterns; it is also an effective way to ruminate on the teaching, planning and needed revisions of learning (Martin et al., 2015).

Moreover, rubrics use a set of specific criteria to evaluate student performance. They may be used to assess individuals or groups and, as with rating scales, may be compared over time. Rubrics have three fundamental features in common (Popham, 1997). First, to assist in identifying the qualities to be assessed, the rubric includes information about which aspects or criteria to look for in student performance. If the rubric is analytic, the assessment criteria are typically presented in separate rows, while if it is holistic the criteria are integrated in the descriptions of the performance levels. Second, to assist in judging the quality of student performance, the rubric includes descriptions of student performance at different levels of quality. By combining the aspects to be assessed with the descriptions of quality into a two-dimensional matrix, along with the third feature, which is a "scoring strategy", a rubric comes into existence (Popham, 1997; Hafner & Hafner, 2003; Reddy & Andrade, 2010; Panadero & Jonsson, 2020).

Rubrics have been used extensively in medical education, interpreting assessment and in many educational situations (both oral and written tasks) to assess student performances. In such situations, many rubrics focused on defining relatively precise descriptions of performance. Such descriptions are believed to promote consistent judgements between markers (Hack, 2015); however, they may also inadvertently limit how generalizable the judgements are to performance contexts where similar skills are required (Timmerman et al., 2011; Popham, 1997). This is a key consideration in assessing student achievement for research projects where the underlying research skills may be deemed more important than specific content knowledge (Moskal & Leydens, 2000). Also, as observed by Walvood and Anderson (1998), a rubric is developed by identifying what is being assessed i.e., specific competence. This is easily observed in evaluation rubrics that were employed in language testing and assessment to measure primary and multiple traits, or competencies, in language production (Cohen, 1994).

Rubrics give "descriptive statements of behaviors that candidates may exhibit in a particular sub-component" (Angelelli, 2009, p. 39). A rubric generally contains all sub-components that constitute the underlying constructs. Since a scoring rubric can be used to holistically score any product or performance (Moss & Holden, 1988; Walvood & Anderson, 1998), it makes sense to discuss its feasibility for scoring interpretation. As declared by Stevens and Levi (2004, p. 3) "At its most basic, a rubric is a scoring tool that lays out the specific expectations for an assignment. Rubrics provide detailed descriptions for what constitutes acceptable and unacceptable levels of performances." Riazi (2003) states that rubrics help translation students and teachers to recognize assessment criteria which are unbiased and objective. Also, rubrics provide ground for reflection, peer review, and self-assessment (Riazi, 2003). Thus, the important point is that by developing a scoring rubric, graders can score all the elements that are relevant to a test. This process confirms the evidence that the constructs which are intended to be measured are not only measured by the test (as a result of careful development) but are also scored by graders (Wiggins, 1998).

An assessment rubric has the sub-components which make the main constructs. Since rubrics are used to assess nearly all products or performance holistically (Moss & Holder, 1988; Walvood & Anderson, 1998), then it can be used on both the main and the sub-components. During interpreting assessment, rubrics allow for more systematic and holistic grading (Angelelli, 2009). Moreover, taking account of translation assessment, rubrics provide more holistic, analytic, and systematic scoring (Angelelli, 2009).

Assessment experts have advocated for the use of rubrics in pre-collegiate and higher education contexts. First, grading is seen to be fairer and more consistent when assessment criteria are made explicit, and instructors describe different levels of performance. Second, self-assessment is valued as a means to help students reflect on their work; rubrics allow students to judge the current quality of their work and the ways in which they could develop it further (Brough & Pool, 2005; Huber & Hutchings, 2004; Walvoord & Anderson, 1998). Thus, by developing an assessment rubric, examiners can assess all the competencies that are related to a test (Wiggins, 1998). A rubric could be generic or task-specific, qualitative or quantitative depending on the scope of work it is intended.

2.14.2 How rubrics support student learning

Evidence abounds in literature of how rubrics may support student learning in different ways, including facilitating the understanding of expectations and feedback, to supporting students' self-regulated learning (SRL). These supports have been reported as providing a sense of transparency of teacher's expectations (Panadero &

Jonsson, 2013; Reynolds-Keefer, 2010); facilitated discernment of areas easily overlooked and discussion of important aspects of teaching not previously noted (Holmstedt et al., 2018); planning, monitoring and evaluation of task performance; assess progress of task using performance criteria (Jonsson, 2014); as well as to make a final check before submitting the assignment for summative assessment (Andrade & Du, 2005; Reynolds-Keefer, 2010). This evidence of support however should not be confused with understanding of criteria nor improved competence because the use of explicit criteria may turn students' attention away from productive learning and focus on surface strategies and "criteria compliance" (Torrance, 2007; 2012)" According to Torrance, the core aspiration of (higher) education should be on students' "autonomous thinking", rather than on the "convergent thinking" that transparency in assessment processes and criteria produce. In other words, learners may just use criteria to improve grade without the assimilation that accompanies understanding and conceptualization of outcomes required of learners as Sadler (2009) argued. His further argument against the use of analytical assessment and pre-set criteria in favor of holistic assessment bringing the notions of emergent criteria and indeterminacy of criteria would easily be flawed by the fairness and transparency requirements of recent assessment research.

Another criticism of the rubric is that the instructor is constrained to following the descriptors, even when some unexpected results of the performance surface, at least until the tool can be redesigned. They can also be time intensive to write at first (Martin et al., 2015). Also, in medical education, rubrics have been used to interpret assessment and assess student's performance. In such situations, rubrics are based on specific competency descriptors that promote consistency between markers (Hack, 2015). However, this may pose possible limitation to how generalizable the judgements will be where similar skills are required (Timmerman et al., 2011; Popham, 1997).

These criticisms against the use of pre-set criteria as argued by authors are only “examples from more extensive literature on the topic. Still, they are interesting because they make strong claims about the limitations and/or consequences from using explicit criteria for formative purposes, which are based on either personal or theoretical considerations, or empirical conditions that are difficult to generalize. This raises interesting questions about the basis for the criticism against the use of explicit criteria and rubrics, such as to what extent these claims are supported by empirical research in how rubrics standardize assessments by providing simple lists of criteria for complex skills and creating a tendency for students and teachers to guide their actions toward those criteria” (Panadero & Jonsson, 2020). Goodrich-Andrade (2006) speaking for rubrics cautioned that “some of the perceived shortcomings of rubrics including the ones listed above, stem from a narrow interpretation that rubrics is a tool for grading rather one that supports understanding”. Huba and Freed (2000) cautioned that “in a well-designed rubric, scoring highly on all of a rubric’s criteria is incompatible with not doing the task well”. In other words, the power of a rubric rests on the degree to which it captures meaningful components of the work without which a quality product could not be achieved. The above was then taken into consideration as we design and construct the rubric.

2.14.3 Design of Rubrics

To develop an effective rubric, especially for an interdisciplinary work, Repko (2008) suggested that it must be established "how each assignment addresses one or more of the cognitive capacities, the relative weight that should be assigned to the different learning outcomes, how every capacity should be tested at least twice in a course at different moments, so the scores can be compared to assess development and how the rubric should be based on previously defined learning objectives". (Repko, 2008). These suggestions have relevant and valid applications to the development of rubrics proposed in this study.

2.14.4 Evaluation of the Design and Application of Rubric

A key issue in evaluating the design and application of rubrics for research projects is whether generic or specific rubrics are selected (Dawson, 2017). Prins et al. (2017) characterized these differences in rubric specificity as top-down versus bottom-up approaches. Top-down approaches, based on theory and expert knowledge, tend to produce rubrics with broader applicability, whereas bottom-up approaches, that use the input and expectations of teachers and students, tend to produce 'context dependent' rubrics, closely aligned with the specific task. Yet, the research evidence for marking consistency with generic and specific rubrics is equivocal. Timmerman and colleagues developed a generic (or 'universal', as they describe it) rubric (informed by content experts and the scholarly literature) to assess scientific reasoning skills in a higher education context, designed to be applicable across tasks, topics, year levels, and even courses (Timmerman et al., 2011). The bottom-up approach appears relevant to this study since learning objectives are already developed in the core syllabi of the program.

The developed iCER-OSH rubric was properly applied to and used to grade students' capstone projects of the CARERC program. The grades were then subjected to a Rasch analysis for its psychometric properties.

Consequently, the present study aims to develop an educational rubric for assessing the interdisciplinary competencies in OSH and investigate the extent to which the diagnostic information of the rubric, is a reliable, accurate, and discriminant method of assessing the specific competencies. To do so, the educational rubric "iCER-OSH" was derived from indicators and learning objectives gleaned from review of literature focusing on interdisciplinary competencies in OSH. The designed iCER-OSH was then employed to confirm the "presence" or "not" of the competencies in the submitted CARERC capstones. The above would be in consonance with other conclusions from literature as to specific competencies that make up an interdisciplinary work (Brandstädter & Sonntag, 2016; Lattuca, Knight, & Bergom, 2013; Pecukonis, Doyle, & Bliss, 2008; Shen, Sung, & Zhang, 2015). Additionally, the study analyzed the actual application of the rubric to confirm the presence of indicators in written capstones projects of the graduated students of the CARERC to validate the evaluation rubric (Baghaei, 2008).

2.15 Rasch Models

Rasch analysis has been employed to analyze the construct validity of the developed rubric for assessing different constructs (Khorami & Modareshi, 2019;

Samir & Tabatabae-Yadzi, 2020) for its peculiar merits. Rasch models hold distinct advantages over related psychometric approaches that have been proposed in an item response theory (IRT) framework. Its prominent advantage lies in its capacity for measurement invariance or specific objectivity (Bond & Fox, 2007; Engelhard, 2008; Fischer, 1995). Measurement invariance implies that test scores are “sufficient statistics for the estimation of examinee measures, i.e., the total number of correct scores of an examinee contains all necessary information for the estimation of the particular examinee’s measure from a given set of observations, and the test is unidimensional, meaning, all items on the test measure the same latent variable or construct” (Kubinger, 2005; Wright, 1999). Rasch analysis is a psychometric technique developed to improve the exactness with which to construct instruments, monitor instrument quality, and compute respondents’ performances. Rasch analysis allows for the construction of alternative types of assessment instruments, that offer the opportunity to modify an instrument to reflect student growth and change. Rasch analysis further facilitates sophisticated ways to measure constructs (variables) (Boone, 2016). Georg Rasch (1960/1980) offered improvement to measurement using his Rasch model to show “how the probability of a student responding correctly to a test question could be modelled as a function of the question’s difficulty and the student’s knowledge”.

Rasch models may be used to address the process of optimizing the number of rating scale points without having to administer several versions of a scale to the same participants (Smith et al., 2003). Once the parameters of a Rasch model are estimated, they are used to compute expected (predicted) response patterns for each item. Fit statistics are then derived from a comparison of the expected patterns and the observed patterns. These fit statistics are used as a measure of the validity of the data model fit and as a diagnosis of individual peculiarity.

The concept of linearity is also a fundamental advantage to understand why Rasch theory is an important tool in measurement research (Boone, 2016). Unfortunately, most data used in psychology and education research are far from being linear measures, yet Psychometricians accede to existence of errors in analyses that assumes raw data to compare student's performance as linear. The temptation to treat exam scale as linear and just "add up" the raw scores of different students to compare their levels of achievement may be high but falling into it must be avoided in the light of current understanding and offerings. Unfortunately, the probability of test item equality in difficulty level is especially low. "Thus, a sum of raw scores cannot be used to achieve accurate comparisons of student performance" (Wright, 1999). The model rests on the fact that, measurements decision in the case of right/wrong test items should "consider the difficulty of each test item along a variable and the overall ability level of a test taker with respect to the variable". "Rasch's model specifies that, when a respondent (B_n on the left side of the equation) answers an item (D_i on the left side of the equation), this relationship will be expressed by the natural log of the respondent correctly answering the item (P_{ni}) divided by the probability of the respondent not correctly answering the test item ($1 - P_{ni}$)". Thus, the Rasch mathematical model (for right/wrong tests) makes use of a single variable, the location of a respondent along the variable, and the location of test items along the variable".

$$B_n - D_i = \ln (P_{ni} /1 - P_{ni}) \qquad \text{Equation 1}$$

In equation 1 above, the dichotomous Rasch model. B_n is the ability of the test taker along the variable; D_i is the difficulty of a test item; P_{ni} is the probability of the test taker correctly answering a specific test item; and $1 - P_{ni}$ is the probability of a test taker incorrectly answering a test item (Boone, 2016).

The Rasch model also assists scale developers reduce clustering of items at the top or bottom of the ruler (or have internal gaps, limiting the ability to detect mid-range variation). With information of this nature, developers can iteratively modify item bank to better reflect the full continuum of each construct (Boone, 2016). Correlations of items, which rest on internal consistency in classical statistics will no longer be readily flagged in scale development, since items though highly correlated, are clustered in specific areas when Rasch analysis is used. The Rasch approach has also helped scale developers construct items such that hypotheses are initiated and tested about expected positions of items and the results feedback has been used to refine construct and rewrite items (Crowder et al., 2019; Gordon, 2015). Specific constructs like aspects of classroom quality, early numeracy teaching as an example, could be carefully defined with a range of items written based on prior studies (including mixed methods, such as thick descriptions of classrooms) to capture a continuum of practices expected to be evident in most classrooms ("easy" items) to those evident in fewer classrooms ("difficult" items). These are represented on the Rasch scale in logit measures reflecting the level of difficulty of items for person's level of ability. The transformation of raw scores into an abstract linear continuum of ability (for individuals) and difficulty (for items) allows one to predict the likelihood of a person choosing, for example, “yes or no” on a specific functional item (Souza et al., 2017). Person and item measures described using the same “logit” unit, create the platform for comparison of a person to other individuals, and an item to other items, or individuals to items (Boone et al., 2014). Additionally, the Rasch model’s conceptualization of items as arrayed along a latent construct differs from classical test theory, that typically rely on inter-item correlations and that sometimes presents items as exchangeable. Rather, the Rasch perspective draws attention to the unique offers of each item (Boone et al., 2014).

When a score deviates from a model’s prediction, this behavior could be scrutinized using unique aspects of the rater, item, and occasion that could have contributed to the result and with possible modification of rater training, item wording, or concept definitions accordingly. This ability to explore the single model about occasion scores, rater agreement, and item modification gives the Rasch model an advantage over traditional approaches e.g., percentage agreement, Kappa scores, and internal consistency statistics (Linacre, 2006). The measurement properties of the Rasch model do not penalize test-takers for taking a harder set of items, nor are they rewarded for completing an easier set of test items. Also, if a judge can no longer “judge” due to getting sick, the candidate will not be rewarded or penalized.

Items with such a range of levels of difficulty in mind help to trim the problems associated with floor and ceiling effects. Also, the wide array of items could also facilitate the detection of change in classroom performance from initial to final aspirational levels. The easiest presentation of these array of levels of difficulty and person's location on the logit scale is the Wright map.

2.15.1 Interpreting the results of Rasch analysis of measuring instruments

Wright maps were designed to compute the difficulty of test items, and the test-item difficulties are expressed on the same linear scale with student's performance (person measure) (Wright, 1996). On the left or "person" side of the Wright map, an "X" is used to plot each of the test takers. The higher the person measures, the better the test performance. The lower the person measure, the poorer the test performance. Wright maps help evaluate how well test items define a variable. They also help "to compare the predicted order of item difficulty with the actual order of item difficulty in a data set". Such comparisons facilitate construct validity assessment showing evidence that the instrument is measuring in consonance with the predicted theory. Wright maps presents multiple avenues to confidently infer from instrument evaluation (Bond, 2004; Boone et al., 2014). Decisions on the Wright map are made when the ordering of items match what is predicted from theory, this provides strong evidence that the researcher has a good concept of what is being measured. The technique for accomplishing this is to evaluate how close the mean item measure ("M" on the right side of the Wright map) is from the mean person measure ("M" on the left side of the Wright map) (Wright, 1996).

The quality of a measurement instrument can also be evaluated by measuring the "fit" of items to the Rasch model (Boone et al., 2014). Fit means that items at the more difficult end of the variable should be harder to correctly answer than items at the easy end of the continuum for all students answering a set of items regardless of their ability levels. Unfit items may indicate that it measures multiple variables. It is critical to identify and possibly remove such items, as the goal of an instrument should only be to measure different parts of a single variable. WINSTEPS (Linacre & Wright, 1999) provides two types of fit statistics for persons and items: Infit is less sensitive to unexpected responses to items far from a person's level of self-efficacy; and Outfit is sensitive to aberrant behavior on items far from a person's level of self-efficacy. In a Rasch analysis, identification of items that do not contribute to useful measurement can be accomplished by reviewing "fit" statistics (e.g., MNSQ Item Outfit, MNSQ Item Infit) for each test item (Boone, 2016). If an item does not clearly fit, often it is best to remove the item from the test and replace it with a new item. There are many reasons why an item may not fit (Wright, 1991). An item may not fit because it is difficult for the sample of students but is unexpectedly answered correctly by a few poor-performing students. An item may be a misfit because it is an easy item that is unexpectedly answered incorrectly by high-performing students. "INFIT" and "OUTFIT" mean square (MNSQ) ranges between 0.60–1.40 is recommended (Bond & Fox, 2007), though there are other recommendations depending on many factors. Unusual response patterns that mislead the analysis and are defined as signs of construct irrelevant variance and multidimensionality (Baghaei, 2008) are shown by values larger than 1.40. Values smaller than 0.60 do not mislead the analysis since they display redundancy of information. They can lead to false high reliabilities (Tabatabaee-Yazdi et al., 2018). Boone (2016) recommends rather to evaluate the Outfit MNSQ statistic for each item to determine if it exceeds

1.3. If so, the item might be misfitting the Rasch model and may be operating in a manner that is not useful for measurement. When reported as mean-square statistics, the Infit and Outfit values are simply chi-square statistics divided by their degrees of freedom. This results in an expected value of 1 and a range from 0 to∞ (Wright & Linacre, 1994). Values less than 1 suggest a lack of stochasticity in the data. Values greater than 1 are indicative of excessive variability.

Rasch analysis also uses the separation index as the reliability indices (Linacre, 2009). Separation reliability shows “how well the person parameters are discriminated on the measure variable” (Tabatabaee-Yazdi et al., 2018, p. 134). Therefore, a high-reliability value signifies a strong association between the items of the test (Samir & Tabatabae-Yadzi, 2020).

Rasch analysis could also be based on the Partial Credit Model (PCM) which specifies that each item has its own rating scale structure. It derives from multiple-choice tests where responses that are incorrect, but indicate some knowledge, are given partial credit towards a correct response. The amount of partial correctness varies across items. Partial Credit Model is designed for scales that have variation in the number and usage of categories across items (Englehard, 2013, P.51) like in Analytic Rating Scales e.g., competencies include many sub scales. Partial credit is thus given to some responses as close as they are to the key (right answer). In all, this model involves an interaction between test-taker ability (Measure) and Item difficulty (Calibration). This analysis in this study was limited to and interpreted by the listed components of the Rasch model itemized above.

2.16 Limitation of the study

This study shall be limited to competencies complemented in literature as interdisciplinary in OSH and the capstones submitted to the CARERC program. This becomes imperative considering that fact that as of now, no consensus definition of interdisciplinarity exist. Also, there is a limited number of students who have graduated from the CARERC program and a few of the students also had their capstone projects missing. This study understands and hope to keep the author's own bias in check while reviewing literatures and in the development of the rubric and assigning the syllabi to the VALUE competencies.

CHAPTER 3. METHODOLOGY

This study evaluated interdisciplinary competencies in written work pieces (capstone projects) of the graduates of the CARERC program. By conducting an extensive survey of literature on interdisciplinarity and competencies, it became possible to arrive at a definition of interdisciplinary competencies in OSH. A dichotomous "Interdisciplinary Competency Evaluation Rubric in Occupational Safety and Health (iCER-OSH)" rubric was developed from the identified indicators/factors of competencies that were complemented by literature to evaluate whether the capstone projects demonstrates that the graduates' utilized the skills, knowledge and abilities that make up interdisciplinary competencies in their capstone project reports and have thus become interdisciplinary competent. The developed iCER-OSH rubric itself was also subjected to a psychometric test using Rasch analysis to ensure its reliability and validity to truly measure the competencies.

3.1 Data Collection

The project sample was the thirty-five (35) capstone project papers of the CARERC program from the online repository domiciled on the project website. The papers were downloaded, and author names and academic institutions were obscured to limit bias in the review process. This repository is not peer reviewed, although each study received institutional review board approval or exception as the case in this study. Authors uploaded capstone projects to the website after approval from their advisory committee, and these are publicly accessible on the organization's website at https://www.uky.edu/erc/trainees/our-graduates.

Ethical Approval

The University of Kentucky Institutional Review Board certified this study as exempt as it did not meet the federal definition of human subjects (45 CFR 46.102(f)).

3.2 Research questions

The purpose of this study was to design a rubric that will confirm if expected interdisciplinary competencies are “Present” or “Not present” in the capstone projects of graduates of the CARERC program. The presence of the competencies indicates that the student understood, utilized and deployed the competencies at the point of need on specific tasks that demanded them. The outcomes of this study would help learners identify the repertoire of competencies they need to acquire in their training to both complete their program and eventually function optimally as competent interdisciplinarians, and teachers fairly assess if training has taken place and ensure program goals are achieved. This is about a valid and reliable rubric; however, it is impossible to develop such a rubric without adequately defining interdisciplinary competency and identifying and compiling the relevant competencies just like this study has done. A lot of issues were considered to arrive at this destination and the guiding questions that lead this journey are as below:

1. How does the literature compliment the expected interdisciplinary competences in Occupational Safety and Health of graduates on the CARERC program?
2. What are the psychometric properties of the developed interdisciplinary competencies assessment Rubric?

An evaluation study like this demanded a broad perspective to a holistic consideration of interdisciplinarity, competencies and rubrics with their needs including its criticisms. A convenient destination was the psychometric calibration of the rubric to ensure it fulfils the reason for its development.

3.2.1 Research Question one:

How does the literature complement the expected interdisciplinary competencies in Occupational Safety and Health of graduates in the CARERC program?

3.2.1.1 Literature Review

Activities to respond to the question above commenced with literature search with interdisciplinary as the keyword on Google scholar and was followed by extensive review of literature on interdisciplinarity including competencies and especially in occupational safety and health to identify the relevant interdisciplinary competencies in OSH. Course objectives and content summaries from courses in each of these areas were also collected and behavioral objectives were identified for comparison with discipline-specific competency sets identified and confirmed from the literature. The review began with about 23 peer-reviewed articles with keywords in interdisciplinarity, interdisciplinary competence, endeavors, habit of mind, integration, program assessment, tasks, science, understanding, writing and in occupational safety and health. A list of competencies from literature was compiled in an Excel file, sorted for duplication, overlap and synchrony, compared and cleaned with relevance to the core syllabi of the CARERC program, a list of expected interdisciplinary competencies in OSH was finally compiled after series of comparison for meaning and relevance around relevant themes. Also, a detailed qualitative description of expected criteria or indicators for each of the competency constructs was compiled leading to an Interdisciplinary Competency Research Evaluation Framework with expected indicators in OSH. Rubric Items were developed into an Item bank in alignment with the Course/Student Learning outcomes that specifically define the interdisciplinary competencies in OSH. A dichotomous instrument iCER-OSH indicating “Yes” for presence of indicator in the capstone and “No” when an indicator is absent in the capstone was developed. This was set up in an Excel file detailing the list of capstone projects and the list of expected competencies and their indicators. Expected components and indicators of the competencies that made up the iCER-OSH rubric were scouted for by reviewing each work through the lens of each indicator in each of the 35 capstones projects. “Yes” was ticked in the Excel file created for scoring if an indicator of competencies was found in a capstone and “No” was ticked if the indicator was not found in the capstone.

This work commenced by conducting an extensive review of literature on interdisciplinarity including competencies and especially in occupational safety and health published by relevant professional associations and credentialing boards in public health, environmental health, and occupational health and safety to identify the relevant interdisciplinary competencies in OSH. This was followed by a dichotomous instrument development process for an interdisciplinary competencies’ evaluation rubric. The instrument development process commenced by considering the content that the instrument would need to assess. Course objectives and content summaries from courses in each of these areas were also collected and behavioral objectives were identified for comparison with discipline-specific competency sets identified and confirmed from the literature. These two sources provided relevant competency statements and indicators that were further refined and developed for this study (Olson et al., 2005). An Interdisciplinary Competency Research Evaluation Framework of expected indicators of interdisciplinary competencies in OSH was first developed prior to the instrument to guide the process. The indicators compiled for the instrument development was ensured to capture students’ understanding of interdisciplinary competencies and their use or application in OSH work or responsibilities as presented in written capstone rather than students’ understanding of individual activities.

3.2.1.2 Interdisciplinary Competency Research Evaluation Framework (iCER-OSH)

Based on the evidence from literature on assessing interdisciplinary competencies in written work, Tripp & Shortlidge (2020) suggested that a framework might be more suitable. It was also argued already that the conclusion was based on the inability of the Boix Mansilla et al. (2009) "Targeted assessment of student's interdisciplinary work" rubric to successfully measure interdisciplinary science due to deficiency in two components of the instrument. This suggestion thus inferred that a rubric developed on a framework designed on a holistic and program targeted perspective would perform better in measuring the goal of this study.

Authors have identified skills including "taking a critical stand on disciplinary limitations, solving complex problems across disciplines, communicating across disciplines, handling interdisciplinary collaboration and teamwork, as well as using integrative potentials to create innovations" (Brandstädter & Sonntag, 2016; Lattuca et al., 2013; Pecukonis et al., 2008; Shen et al., 2015). Meanwhile, identifying and adequately assessing these skills in written work has been challenging, with no currently existing rubric to evaluate the presence or absence of the competencies in any written work (Reid et al., 2022). This study fills this gap using the written capstones of the graduates of the CARERC program. Interdisciplinary competencies for this framework were based on the definition developed for this study. An Interdisciplinary Competency Evaluation Rubric in Occupational Safety and Health (iCER-OSH) rubric was then developed from the above framework in order to adequately capture interdisciplinary competencies in the CARERC capstones.

3.2.1.3 Program and Course Outcomes

Review of literature has shown that the field of OSH requires interdisciplinary competent professionals (Olson et al., 2005; Daud et al., 2010; Newton et al., 2012) and that these can only emerge depending on the kind of training they were exposed to. Such training must have learning objectives that are truly designed to develop relevant and necessary competencies in them. The above completely agrees with the principle of constructive alignment. Meanwhile, a fundamental principle of constructive alignment is that the curriculum is designed in such a way that the learning activities and assessment tasks are aligned with the intended learning outcomes (ILOs), what the students should be able to do or demonstrate. Also, constructive alignment is about ensuring that assessment, teaching, learning and feedback should be synchronous with each other, and that feedback links well to students' evidence of demonstrating their achievement of the intended learning outcomes (Ali, 2018). Course objectives and content summaries from previous empirical studies relevant to discipline-specific competency sets from the literature were harvested and set in the framework above. From this, competency statements relevant to the practice of occupational health and safety were identified and refined. The above principle informed the design of the descriptors/indicators in the developed rubric and assisted in conceptualizing the interdisciplinary competencies constructs of the rubric and on the assumption that training was done in synchrony. The principle of constructive alignment has been employed as frameworks for quality assurance agencies in the UK and Hong Kong (Rust, 2002). Edström (2008) writes that: “course evaluation should be regarded as a component of constructive alignment, together with the ILOs, learning activities and assessment.” Constructive alignment is widely regarded as a key idea for postgraduate certificates in higher education (Kandlbinder & Peseta, 2009).

The three main stages involved in applying constructive alignment to teaching are evident in the design of the CARERC program and the goal of this study as the designed ILOs and, the structure of teaching/learning activities (TLAs) are clear in the core syllabi, while the designing and aligning assessment tasks to evidence from literature was done in this study. Finally, a holistic logic assessment is expected in constructive alignment (Biggs & Tangs, 2015) and this study has proceeded to check the presence of the expected learning objectives and their indicators in the submitted capstones.

Rubrics are composed of sets of specific criteria that define or describe the target variable (interdisciplinary competencies in this study) in ways that each criterion is deconstructed into components and sub-components. The components and its subs that fully illustrate interdisciplinary competencies in OSH were identified, described and aligned to develop this relevant rubric. This builds from evidence that such a rubric will help evaluators check all the relevant elements in a test. Thus, the intended constructs are then measured by the test that was carefully designed (Wiggins, 1998). To find the constituents of the iCER-OSH rubric, the following steps was followed:

Further, identifying the components of competencies and sub-competencies in interdisciplinary OSH followed. A list of competencies from literature was first compiled in an Excel file, sorted for duplication, overlap and synchrony, compared and cleaned with relevance to the core syllabi of the CARERC program, a list of expected interdisciplinary competencies in OSH was finally completed after series of comparison for meaning and relevance. Interdisciplinary Competency Research Evaluation Framework was developed from the above and other relevant descriptors complemented from literature to evaluate students' demonstration of interdisciplinary competencies in OSH by their written capstone submissions. Then a detailed qualitative description of expected criteria or indicators for each of the competency construct was compiled and developed to confirm if the interdisciplinary competencies in OSH are present or not present in the submissions (Reid et al., 2022) so teachers and students will understand the expected qualities. Rubric items were developed into an Item bank in alignment with the Course/Student Learning outcomes that specifically define the interdisciplinary competencies in OSH. Finally, a dichotomous design of "present" is “one” and “not present” is “zero” was decided to progress from rubric scores to a final grade when applied to the capstone projects of the CARERC graduates.

3.2.1.4 Components and Indicators of iCER-OSH

A robust definition of interdisciplinary competence in OSH would require graduates of CARERC program to: “be able to successfully apply critical work tasks, specific functions, or operate in a specified OSH role or position to demonstrate cognitive advancement due to their acquired capability to consistently apply, use or integrate knowledge, skills, abilities (KSA), behaviors, and personal characteristics effectively as afforded by collaborative merger of more than one disciplinary lens of OSH disciplines. They should demonstrate the skill to integrate knowledge and modes of thinking from two or more disciplines which results in a cognitive advancement, such as explaining a phenomenon, solving a problem, or producing a product, which would not have been possible if solely the knowledge of one discipline had been used. Newell (1998, 2002) identified 21 cognitive skills that could define integrative work, including critical thinking, sensitivity to bias and ethical issues. ACOEM guidelines (1998), had recommended that the desired competencies for occupational and environmental medicine (OEM) will require “a menu of defined and demonstrated subject matter expertise (demonstrated proficiency) in at least one of the relevant disciplines plus cross-cutting skills including a basic understanding of, and experience in, data collection methods, research design, and data analysis methods related to the individual’s primary profession and adapted to broader workplace safety and health issues”. This set of competencies also includes the application of risk assessment and analytics to strategic decision-making and should have the ability to effectively design, implement, and evaluate programs, policies, and procedures by applying best practices to optimize adoption and sustainability. These set of OEM competencies were later updated in 2008 and again in 2014. The expected interdisciplinary competencies should thus be in line with the above.

Thus, Physicians practicing OEM are expected to "understand how to recognize, prevent, evaluate, diagnose, treat, and manage adverse health effects from workplace and environmental hazards, as well as, how to create and promote a culture of wellness in the workplace" (ACOEM, 2020). Olson et al. (2005) in their paper confirmed that most program-eligibility requirements for ERCs stated that trainees must be "exposed to the principles of all other occupational safety and health core and allied disciplines" and centers "must give special, innovative, attention to thoroughly describing the approach for fulfilling interdisciplinary interaction among students".

First, all statements related to graduate student qualities or learning outcomes were extracted. The extracts were then aligned with the relevant constructs of the interdisciplinary competencies in OSH from literature. Although there are expected important overlaps and connections among these components, attempts were made to develop distinct categories that reflect the descriptions embedded in the definitions in ways that can extend or be extended by the literature. Following the above activities, relevant components compiled from literature and compared with learning outcomes in the core syllabi includes the underlisted 10 expected components or criteria of interdisciplinary competencies in OSH: Demonstration of grounded understanding of their primary discipline; Recognition of determinants and enablers of OSH challenges; Identification of OSH issues and problems; Assessment of OSH issues; Recognition and acceptance of its own limitation to adequately proffer solution to problems; Capacity to control and prevent OSH challenges and problems; Understanding of both the ethical and legal regulations around OSH issues and problems; Evaluation of the impact of OSH issues and problems; Communication and effective reporting of OSH issues and challenges; Collaboration and team work and proffering/ applying integrated and creative well consulted solutions with other disciplines for cognitive advancement in OSH. Expected components and indicators of the competencies that made up the iCER-OSH rubric were scouted for by reviewing each work through the lens of each indicator in each of the 35 capstones projects and these are discussed below:

3.2.1.4.1 DISCIPLINARY GROUNDING

Grounded understanding in one's primary discipline can be viewed as "the degree to which student work is grounded in carefully selected and adequately employed disciplinary insights" (Boix Mansilla & Duraisingh, 2007, p. 222). This is a prerequisite provisional grounding or understanding for learners before they can draw the links between disciplines. Boix Mansilla & Duraisingh (2007) reported that faculty experts felt that students did not need to master each of the contributing disciplines but that they did need enough depth to reflect on the nature of disciplines and make meaningful connections. This component reflects how current knowledge and understanding in one's field of practice are demonstrated by students. Boix Mansilla & Duraising (2007) suggested that "assessing interdisciplinary work involves carefully considering its disciplinary grounding by a focus on selection (of disciplines and insights) and appropriateness (in the use of knowledge and modes of thinking)". Relevant items to assess this include among others: Are the selected disciplinary insights fit to inform the issue at hand? Are any key disciplinary perspectives missing? Are the considered theories, examples, findings, methods, and forms of communication employed in accordance with their disciplinary origins, or does the work exhibit misconceptions? Close disciplinary reading of student work should unearth the foundational bodies of expertise on which a piece stands. Targeted and informative feedback then becomes possible.

3.2.1.4.2 RECOGNITION OF DETERMINANTS AND ENABLERS OF OSH CHALLENGES

Another component that becomes evident from literature is the ability to recognize the determinants and enablers of OSH challenges (Olson et al, 2005). This was interpreted as being able to recognize the influence of cultural and social factors in occupational health and safety practices or demonstrate awareness of diversity in social and cultural beliefs as relates to OSH problems, it may also signify understanding the relationship between occupational exposures and health outcomes.

3.2.1.4.3 CONTROL AND PREVENTION OF OSH ISSUES AND PROBLEMS

Another component of interdisciplinary competencies in OSH as reflected by literature is the capacity to control and prevent OSH issues and problems. This was interpreted as ability or capability to observe, point out, appraise, or gauge health and safety hazards of work site processes and operations as well as observe and point out, appraise or gauge OSH challenges, risks, and opportunities. It progresses to being able to easily identify and recognize missing gaps in implementing OSH plans and effectively implement multi-task OSH workflow plans (Olson et al, 2005).

3.2.1.4.4 DISCIPLINARY HUMILITY

This is the habit of mind characterized by comprehensive exploration of issues, ideas, or events to observe, identify and point out one's own limitations to offer any resolution without help from others. "It is developing a mindset, or epistemic perspective, that is infused with humility, inclusivity, and respect for other disciplinary epistemologies" (Tripp & Shortlidge, 2019). This mindset reflect easy recognition in disciplinary personnel gaps in OSH plans, can assemble teams of multiple disciplines to resolve OSH issues, demonstrates the ability to easily adapt to broader workplace safety and health issues, seek out diversity of perspective, attempt to embrace contradictions, and looks for strengths in arguments the authors dislike and weaknesses in those they like.

3.2.1.4.5 UNDERSTAND THE ETHICAL AND LEGAL REGULATIONS AROUND OSH

This is a state of mind that consciously seeks to interpret and apply cautionary outlook to ensure that humans and environment are protected in the application and integration of knowledge to solve problems. The good of all is considered the desired good right from conception to implementation of ideas. It both sets up consensus rules and regulations to guide how issues are resolved (ACOEM, 2020). It could also mean identifying ethical dilemmas and working in an ethical manner, knowing occupational safety and health laws and regulations, understanding the ethical issues around OSH, applying the understanding of ethics, laws and regulation in implementation of programs, understanding and applying relevant laws and regulations, managing financial resources effectively, and recognizing the principles of all other occupational safety and health core and allied disciplines.

3.2.1.4.6 COMMUNICATION

Interdisciplinary Communication was defined as the ability to communicate across disciplines by looking beyond differences in terminology and identifying the overlap among concepts and methods used by disciplines. Interdisciplinarians help promote unity and understanding through effective written and verbal communication (Ciraldo, 2020). This communication and reporting build and interpret an individual's ability to communicate effectively with a variety of stakeholders (e.g., management, labor); to present ideas and opinion in a clear and holistic way; to write well in order to communicate opinion and issues in a clear and holistic manner; to interpret and disseminate policies clearly; and to communicate effectively with other safety and health professionals.

3.2.1.4.7 COLLABORATION

Collaboration is a behavior controlled by individuals to put effort into team tasks, it manifests in the manner of interacting with other people on the team and is measured by the quantity and quality of contributions individuals make to team discussions (VALUE ®). Bronstein (2003) has described a model consisting of five components that constitute interdisciplinary collaboration between social workers and other professionals: interdependence, newly created professional activities, flexibility, collective ownership of goals, and reflection on process. Also, Petri in 2010 described necessary elements to make an interdisciplinary collaboration successful: interprofessional education, role awareness, interpersonal relationship skills, deliberate action, and support. The above stems from the humble realization of the need for others to complement specific gaps in a piece of work to make it whole. Students are involved with others on a team in varied activities like laboratory assignments, oral presentations or field work and each student on the team is diverse in skills, disposition and abilities. The assumption here is that a work sample demonstrates the contribution of the student as complimentary input to the team's overall output and could span a continuum from mild to dominant (Fewster-Thuente et al., 2008). Indicators of this criteria in OSH are the individual's unique disciplinary contribution to team objectives at meeting, facilitation of the contributions of other team members, individual's contributions outside of team meetings, how the individual fosters constructive team climate and the person's response to conflict. It is also evident in how effectively a person functions in an interdisciplinary team, how the person manages staff/personnel resources effectively, and how effectively, the person displays leadership over multiple team members and activities and harnesses team's potential for ultimate group goal (Olson et al., 2005).

A capstone project would therefore reflect the above-listed indicators as evidence of individual's interaction within a team. Unfortunately, studies have shown that a written report is usually insufficient as it usually does not provide insight into the functioning of individuals in a team. It is thus recommended that samples or collection of work from other sources like student's own reflections, evaluation feedback from fellow team members and an outside observer's evaluation regarding the student’s contribution to a team’s dynamics would be complimentary (Tripp & Shortlidge, 2020). The focus on disciplinary contribution of team members separates this from regular teamwork.

3.2.1.4.8 INTEGRATION

Integration is a perception or inclination learners develops across curriculum and disciplines that enables simple connections of ideas and experiences from multiple disciplines to synthesize and transfer learning or tasks to produce cognitive advancement like solving a problem, employing a new methodology, or writing a new procedure or scheme. Ideally, learners garner from previous and current learning experience and other disciplinary boundaries, synchronize and design a significantly different knowledge from those backgrounds, possibly initiating or situating another discipline (Boix Mansilla & Duraising, 2007; VALUE®). This is also the ability to pull concepts together from other disciplines to proffer integrated and creative solutions to OSH challenges (Olson et al., 2005). It can still be viewed as designing and delivering adult education programs in OSH; designing and implementing changes in OSH work environments; formulating and implementing guidelines and policies in OSH; creating and promoting a culture of wellness in the workplace; and demonstrating attention to thoroughly describing the approach for fulfilling interdisciplinary interaction among peers.

“Indeed, integrative experiences often occur as learners address real-world problems, unscripted and sufficiently broad, to require multiple areas of knowledge and multiple modes of inquiry, offering multiple solutions and benefiting from multiple perspectives” (VALUE®). Integrative learning, a precursor to integration, also involves changes within the learner. These internal changes, indicating growth as a confident, lifelong learner, incorporates adaptability of intellectual skills, thereby enabling contributions to varied situations and ultimately influencing individual's perspective on purpose, values and ethics. Fostering students' capacities for integrative learning becomes the foundation to personal success, social responsibility, and civic engagement.

Integration is the most challenging of the competences to assess in written pieces except students are deliberately required to frontally present evidence in their reports (Boix Mansilla et al., 2009; Reid et al., 2022). However, the connections seem more visible in reflective work, self-assessment, or creative endeavors of all kinds (Drake & Reid, 2017).

Criteria and indicators of integration are the ability to connect to prior experience (connect relevant experience and academic knowledge); connect to discipline (seeing/making connections across disciplines, perspectives); transfer by adapting and applying skills, abilities, theories, or methodologies gained in one situation to new situations; integrated communication; reflect and self-assess (demonstrating a developing sense of self as a learner, building on prior experiences to respond to new and challenging contexts which may be evident in self-assessment, reflective, or creative work). Easier ways to enhance the above could be composition papers that focus on topics from a range of disciplines" or tasks requiring multiple methodologies. "The key in the development of such work samples or collections of work will be in designing structures that include artifacts and reflective writing or feedback that support students' examination of their learning and give evidence that, as graduates, they will extend their integrative abilities into the challenges of personal, professional, and civic life" (VALUE®). Integration is one of the most challenging elements to assess the components of interdisciplinarity.

3.2.1.4.9 Creative thinking

"Creative thinking is both the capacity to combine or synthesize existing ideas, images, or expertise in original ways and the experience of thinking, reacting, and working in an imaginative way characterized by a high degree of innovation, divergent thinking, and risk taking" (VALUE®). It can also be seen as reflective thinking to apply holistic well-thought out and consulted plan to OSH issues; the ability to design and initiate research or work processes on multiple methods and knowledge sources; to design and implement screening programs based on multiple methods and knowledge sources to address a problem; to design and implement surveillance systems from exploring methods complimentary from more than one discipline; to design and implement health promotion and education programs; to design and implement work process interventions built on more than one disciplinary approach; to develop and implement health and safety programs; to apply best practices to optimize adoption and sustainability and to look for unexamined linkages and unexpected effects in program activities.

3.2.1.4.10 Evaluation

This is the ability to measure and assess the effectiveness of OSH environments, programs and policies using data obtained to make sound and informed judgements and decisions about them. It is a familiarity with the ways in which health risks in the workplace can be anticipated, recognized, evaluated and controlled (Lattuca et al., 2012). It begins with an understanding of the strategies and methods available for evaluation and recognizing their limitations and constraints. It includes analysis of data and research methods using biostatistics theory and concepts. It may also involve the review of occupational and environmental epidemiologic literature in a systematic and critical manner for assessing disease and injury associations and assessing risks of occupational environments. It demonstrates the ability to assess and critically review literature in a substantive area of research, be able to identify gaps in knowledge and be able to formulate original research hypotheses or statements (Newell & Luckie, 2019). Lattuca et al., (2012) however, stressed the need for students to be more aware and appreciative of knowledge, methods, and perspectives of their own and other disciplines despite the fact that no good method has been developed of interdisciplinary evaluation and even until now.

3.2.1.5 Item bank development

Indicators of the above expected competencies were harvested from the review of literature and the core syllabi of the project. These were compiled onto an excel file to check for relevance, complementarity, and inference to the concluded competencies. The compiled indicators were later sieved and pruned to remove duplicity, repetition and ambiguity. This was followed by a back-and-forth comparison with the definitions, conceptual and contextual interpretations of the competencies around the literature and core syllabi to ensure adequate representation and definition of each expected competency. An initial bank was developed, used as a pilot for the capstones. This bank was presented to the committee members who reviewed and pointed out areas of multi-barrel and redundance that could undermine the face validity of the instrument. The initial review result was discarded while the items were reworked upon and re-presented to committee members for approval and continuity. The emergent item bank was utilized to review the capstone projects for the second time and evidence of presence or not of the indicators of the competencies.

3.2.1.6 Interdisciplinary Competency Evaluation Rubric in Occupational Safety and Health (iCER-OSH)

This study, contrary to other interdisciplinary rubrics assessing capstone /thesis/terminal papers opined that a robust rubric would not just assess the component competencies that measures only the technical competencies but would holistically evaluate all the competencies that would be required of a proficient graduate of interdisciplinary competent Occupational Health Safety program of CARERC as presented in its core syllabi.

A productive design of the framework demands first a careful consideration of "what are the disciplinary understandings that the courses sought to develop? How might students exhibit critical awareness in this project? Questions of this kind enable this work to tailor the framework to the content areas and to consider the aims and objectives in the CARERC syllabi. The iCER-OSH tool was developed on the components of competencies in the literature demonstrating clear learning goals and objectives of the OSH. The purpose of which would be beyond making pass/fail decisions but rather an instrument that guides both the teachers and learners on developing a robust and competent interdisciplinarian.

The CARERC program trains at four levels of study namely Master of Science (MSc), Master of Public Health (MPH), Doctor of Public Health (DPH) and Doctor of Philosophy (PhD). The submissions would also be categorized by the level of study as shown in Table 7 and the developed rubric was applied to evaluate individual submissions based on its level of study. The core syllabi of the CARERC project presents the learning objectives that will inform the kind of competencies expected of each student exposed to the training and which they must demonstrate in their capstone experience and especially in their final written submissions. These learning objectives are components of the core courses each participant must be exposed to irrespective of their level or discipline of study. The discipline and level of study and their distribution among the sample are presented in Table 7 below:

Table 3.1 Distribution of submission of CARERC Capstones by level of Study

Level of Study	MSC Occupation al Safety)	MSC (Mining and Health Safety	MPH Agricultural Health & Safety (Environment al Health)	MPH Occupationa l Epidemiolo gy	DPH Occupationa l Epidemiolo gy	PhD Occupational & Environmenta l Health Nursing	Total Submission
No of submission	5	3	16	5	5	1	35

A starting point for item construction was to write items that reflected the major components or criteria of the interdisciplinary competencies construct. Once written, items were reviewed with the dissertation committee to categorize the items as reflecting the task and goal of the construct. This was done to check understanding of the construct and to make sure items accurately reflect the parts of the competencies they were originally designed to capture. Based on the feedback received, items were refined, eliminated, or rewritten to adhere to both psychometric guidelines and theoretical integrity. Following this, the final iCER-OSH item pool was subjected to Rasch investigation to confirm its psychometric properties.

3.2.2 Research question two

What are the psychometric properties of the developed Interdisciplinary Competencies evaluation rubric in Occupational Safety and Health (iCER-OSH)?

One way to ascertain that the developed iCER-OSH rubric measures what it was designed to was to subject it to a Rasch measurement. The Rasch method is useful for evaluating reliability and validity of assessment and testing instruments like rubrics. Reliability and validity are important components of psychometric tools and evaluating them is advised prior to putting test instruments to general use (Aryadoust, 2016).

Research question two was answered in two stages as shown below:

3.2.2.1 Stage one: Implementing the Rubric in scoring the Capstone Projects

In this stage, the capstone projects of the CARERC program (Total sample of 35 submitted capstone projects) were reviewed with the iCER-OSH approved Rubric. The presence of an indicator designated as “Yes” or “Not present” designated as “No” would be recorded and stored for psychometric analysis using Rasch Model. The final iCER-OSH rubric employed in this study consisted of four (4) interdisciplinary competencies components that emerged from interdisciplinary thinking in the iCER-OSH framework with their relevant indicators and items were stored in a bank. Resulting data coded as “Yes” is “1” and “No” is “0” is imported into Winsteps for model analysis and the underlisted parameters were checked, recorded and interpreted.

3.2.2.2 Stage two: Calibrating the Rubric

In calibrating the rubric, the following questions are usually asked to design a great instrument (Wjr, 2015): How reliable and valid are the items of the rubric and the rubric itself to measure Interdisciplinary competencies in OSH? What is the range of difficulty of the instrument’s items, the difficulty of tasks, the difficulty of individual items, and the hierarchy of item difficulties. This study utilized a Rasch analysis to investigate the appropriateness of the iCER-OSH rubric and examine whether all the items contribute to evaluate interdisciplinary competencies in OSH in the CARERC capstone projects. Also, the Rasch analysis was used to check whether the iCER-OSH rubric discriminates well between the capstone projects in reflecting the OSH competencies of the CARERC program.

The outcome of the review of capstones to reveal "presence of" or "not" of the indicators of interdisciplinary competencies were entered into a Microsoft Excel file, coded and imported into the WINSTEPS software for the psychometric analysis using Rasch Model. Only the second review results were used at this stage of the analysis.

3.2.2.3 Rasch Model

The Rasch software program, Winsteps 5.3.2 (Linacre, 2022), a user-friendly program, was used to examine the functional items from the reliability and separation of item and respondent, polarity and items fit measuring constructs and standardized residual correlation value. The iCER-OSH Rubric was calibrated based on the underlisted characteristics of the Rasch Model:

3.2.2.3.1 RASCH MODEL FIT MEASURES

Individual item and person fit was analyzed using Infit and Outfit statistics to indicate how well data conformed to the Rasch model. For each one of these fit statistics, Winsteps provides Mean Square (MNSQ) and Z-Standardized Scores (ZSTD) (Boone et al., 2014). Ideally, it is recommended to begin fit analysis by looking at Outfit before Infit, and MNSQ before ZSTD. The expected value for MNSQ is approximately 1.0, and values between 0.5 and 1.5 are considered productive for measurement (Linacre, 2012). If the MNSQ value is beyond this range, ZSTD must be checked– ZSTD values of 2.0 or more indicate statistically significant model misfit. Misfits are unusual response patterns that mislead the analysis and are defined as signs of construct irrelevant variance and multidimensionality (Baghaei, 2008). They are shown by values larger than 1.50. Values smaller than 0.50 do not mislead the analysis since they display redundancy of information. They can lead to false high reliabilities (Tabatabaee-Yazdi et al., 2018).

In this study, because the items were rated using a dichotomous scale, an item with more than 50% unexpected variance than the model predicted (i.e., infit MS > 1.5) was considered as misfitting. A misfitting item could infer a different dimension or may not discriminate appropriately between participants. Items exceeding the above criterion were taken as noisy to the model and thus removed. This process of removing misfit items and re-calibration of the remaining items in the instrument continues by serially removing misfit until the instrument presents a good fit for all items. The remaining items were re-calibrated till a good fit is achieved for all items. Some cautions however were also taken to ensure that items with strong relevance are not to removed so as not to significantly alter the meaning of the underlying construct of interdisciplinary competencies in OSH. Omission of misfits was sustained until a reasonable total fit was attained.

3.2.2.3.2 SEPARATION AND RELIABILITY

Based on the Rasch measurement model approach, the acceptable reliability Cronbach's Alpha (α) is between 0.71- 0.99 where it is at the best level (71% - 99%) (Bond et al., 2007). Reliability was evaluated using the indices provided by WINSTEPS: person separation index, person reliability, item separation, and item reliability. The reliability reports how reproducible the person and item measure orders (i.e., their locations on the continuum) are (Linacre, 2012). Overall, validity focuses on broader issues of appropriateness and alignment of the rubric with the purposes of the assessment and the learning context (Andrade, 2010; Johnson, 2007).

The separation indices give an estimate of the spread of items or individuals along the continuum of ability and reflect the number of distinct strata in which the sample or items can be divided (Bond & Fox, 2015). A person separation index of 1.5 or a person reliability coefficient of 0.7 represent an acceptable level of separation and is considered the minimum required to divide the sample into two distinct strata i.e., low and high ability (Wjr, 2015). A person separation index of 2.0 and a person reliability of 0.8 represent a good level of separation and are considered the minimum preferable values (Linacre, 2012). Item separation index and item reliability are interpreted using the same criteria. According to Rasch guidelines, if the item reliability and separation are below the required values, a bigger sample is necessary; if the person reliability and separation are below the required values, the test needs more items (Linacre, 2012).

Evaluating the validity of a rubric is a complex process based on multiple sources of evidence. Multiple frameworks for validation processes exist, including traditional approaches based on considerations of the content, construct and appropriate criteria (Moskal & Leydens, 2000). More recent validity frameworks focus on the context of the assessment, in addition to validity inferences drawn from aspects such as scoring process, generalization, extrapolation and educational implications (Cook et al., 2015; Kane; 2006). The first two of these, namely scoring and generalization, are particularly relevant to rubrics. Jonsson and Svingby (2007) noted that while scoring with a rubric is likely to be more reliable than without a rubric, the same cannot be said about validity (p. 137). The validity of a rubric, they argued, is strongly influenced by its alignment with the relevant learning objectives;

in other words, the link between skills or performance is endorsed by the rubric and the pedagogical context and purpose.

Validity is a more difficult issue, as the empirical assessment of the instrument's ability to distinguish between groups suggests that it should theoretically be able to view as distinct (Trochim, 2003). Essentially, the idea is to start with two groups that have differences and demonstrate whether the instrument is able to significantly measure those differences (Wolfe & Haynes, 2003; Trochim, 2003). A test or questionnaire is said to be valid when the items' underlying construct causes the item responses (Baghaei & Tabatabaee-Yazdi, 2016)

3.2.2.3.3 INDIVIDUAL ITEM CHARACTERISTICS

iCER-OSH item difficulty and person ability was plotted graphically in a person-item map. The person-item maps (also called Wright Maps) allow for a visual analysis of the relationship between the measures of individuals and items. The use of these maps assists in the assessment of positive and negative issues, such as item redundancy (i.e., items at the same difficulty level), trait gaps (that may indicate the need of more items to fill the gaps), ordering of items matching the prediction of the test author or users (i.e., construct validity), and targeting between the items and sample (i.e., whether item difficulty range matches the sample ability range) (Boone et al., 2014)

Parameter and coding scale for the data entry and analysis for this study is presented in Table 3.2 below: Each parameter is represented in the code presented in the table and is thus used for the analysis in the WINSTEPS software.

Table 3.2 *Parameter and Coding table*

Parameter	**indicator**	**Coding Key**
Dept	Occupational Epidemiology	1
	Agricultural Health & Safety (Environmental Health)	2
	Occupational Epidemiology	1
	Mining and Health Safety	3
	Occupational Safety	4
	Occupational & Environmental Health Nursing	5
Program	DPH	1
	MPH_Ag	2
	MPH_Oc	3
	MS_Mi	4
	MS_Oc	5
	PhD	6
Item	Yes (Present)	1
	No (Not Present)	0

This chapter focused on the methods and approaches to respond to the research questions raised to guide this study. It proceeded to elucidating how the competencies and their indicators would be teased out, leading to how the iCER-OSH framework and item banks would be developed and eventually calibrated using Rasch analysis.

CHAPTER 4. RESULTS

The purpose of this study was to develop a rubric for evaluating the interdisciplinary competencies in written work pieces (capstone projects) of the graduates of the CARERC program. An extensive survey of literature on interdisciplinarity and competencies was conducted to arrive at a definition of interdisciplinary competencies in OSH. A dichotomous "Interdisciplinary Competency Evaluation Rubric in Occupational Safety and Health (iCER-OSH)" rubric was developed based on the identified criteria and indicators of competencies in OSH as complemented by literature. The developed iCER-OSH rubric was used to evaluate whether the capstone project reports of the graduates reflect that they have the skills, knowledge and abilities that make up interdisciplinary competence in OSH and have thus become interdisciplinary competent. Prior to now, empirically developed rubrics evaluating interdisciplinary competencies in written reports were scarce, especially in OSH. The CARERC program has also been desirous of a rubric to both guide assessment and confirm that students of the program are demonstrating expected proficiency in interdisciplinary competencies as projected in this study. The developed iCER-OSH rubric itself was also subjected to a psychometric test using Rasch analysis to ensure its reliability and validity to truly measure the competencies. Thirty-five (35) CARERC capstone project papers of the CARERC program were downloaded from an online repository on the project website. The downloaded papers were reviewed dichotomously with the iCER-OSH rubric and the rubric was calibrated with Rasch analysis via the user-friendly Rasch software program, Winsteps 5.3.2 (Linacre, 2022). No demographic or identifying information was collected since this study was only meant to calibrate the developed rubric in order to provide a reliable and valid desired rubric for the CARERC program.

Activities to determine what constituted the components of the competencies considered appropriate as expected interdisciplinary outcomes included the extensive review of literature, compiling relevant competencies and indicators into an Excel file, sort the list into thematic areas and for duplication, merging and synchronizing related themes, comparing the list with the learning objectives from the core syllabi, defining interdisciplinary competencies in OSH and finally concluding on the list of competencies for the development of the iCER-OSH rubric. Tables 2, 3, 4 and 6 were consulted as summaries of the major skills and thinking of interdisciplinary capacities and competencies by various authors (Newell et al., 1990; Field, 1994; Cornwell & Stoddard, 2001; Olson et al., 2005; Boix Mansilla & Duraising, 2007; Repko, 2008; Mentkowski & Sharkey, 2011; Lattuca et al., 2012; Drake & Reid, 2017; El Asame & Wakrim, 2018; Claus & Wiese, 2019; Newell & Luckie, 2019; Tripp & Shortlidge, 2019)

The first step to identifying expected competencies was compiling words and statements relevant to interdisciplinary competencies from the literature and core syllabi of the CARERC program. In addition, the words and emerging themes were synchronized across the literature and core syllabi. Next step was finding common themes and related terminologies and classifying them into specific competency groups. The themes that emerged were finalized and set in Table 4.1. Some of the components of emerged themes were taken as indicators to measure them as presented in Table 4.1. The iCER-OSH rubric consists of ten (10) criteria and eightyone (81) indicator items based on a dichotomous scale ranging from yes (interdisciplinary competencies in OSH is present in capstone project) to not present. Each of the item inquiries are directly related to one of the ten main criteria complemented by literature which guides this project.

Proceeding from here, all 35 capstone projects were reviewed using only four of the interdisciplinary competencies in OSH. The four competencies this study focused on in this stage emerged from the disciplinary thinking locus of iCER-OSH framework and are Integration (8 indicators), Collaboration (7 indicators), Creative thinking (13 indicators) and Communication (6 indicators) for a total of 34 indicators of four competencies.

All 35 downloaded capstone projects were reviewed through the lens of the 34 indicators of the four competencies. The presence of indicators was checked in all sections in each of the capstones. Every indicator found was ticked “Yes” in the rubrics table and absence was ticked a “No”. Each capstone was reviewed twice to ensure that some indicators were not omitted or overlooked. Indicators that had conflicting checks after the second review of capstone were re-reviewed in the specific sections and the conclusion at the third sectional review was taken as final. The third review (sectional) was necessary, as we could not conclude presence or not on mean responses of each indicator since responses were expected to be dichotomous and mean response of each indicator would be confusing in response. This review followed an initial review that was discarded due to inadequate instrument design observed by members of the advisory committee.

In the process of the capstone review, about 8 items of the iCER-OSH instrument were modified for grammar or were expanded or split to better capture the presence of the competencies.

By developing the rubric, a standard to either assess or evaluate the presence of interdisciplinary competencies in student's work as OSH experts is presented. This fulfils the long-awaited program desire to be able to assess and evaluate its effectiveness, interpret transparently what components of OSH competencies to look for in student written pieces as evidence of learning, and present to students a transparent expectation of learning goals and finally to the program an evaluation scale. This is significant considering that rubric related to measurement quality (particularly for research projects) are scarce (Reid et al., 2022) and that there is the urgent need to generate empirical data to guide rubric design and implementation (Panadero & Jonsson, 2020), especially program specific evaluation rubric that will meet the needs of the of OSH programs and emerging interdisciplinary fields. The result of this study emanated from three core areas:

1. Literature on interdisciplinarity and competencies especially in OSH,

2. How the literature complemented expected interdisciplinary competences in Occupational Safety and Health of graduates in the CARERC program and

3. Rasch calibration of the developed iCER-OSH rubric.

This rubric would help faculty on the program adequately assess for relevant competencies, help students understand expectations clearly, help program owners with scale to evaluate, and help other researchers identify relevant criteria and indicators of interdisciplinary competencies. Results are as presented below:

4.1 Research Question One

How does the literature compliment the expected interdisciplinary competences in Occupational Safety and Health of graduates on the CARERC program?

Expected interdisciplinary competencies in OSH were collected and assembled from literature review on interdisciplinarity, interdisciplinary understanding, competencies, and interdisciplinary and crosscutting competencies. These were also compared with the core syllabi of the CARERC program. The process commenced with reviewing 23 peer-reviewed articles, resulting from a search on Google Scholar on interdisciplinarity, most of which have been summarized in Tables 2 (pg. 17), 3 (pg. 21), 4 (pg. 30), 6 (pg. 46). All themes and indicators of definition or assessment of these competencies from the literature on interdisciplinary skills, competencies, capacities, habit of mind, thinking and understanding were collected and entered in an Excel spreadsheet. Some of the articles presented the skills, competencies and capacities as themes needing redefinition, with indicators or already defined with clear indicators of measurement. Initially, 69 thematic areas were identified with 117 indicators. Many themes and indicators were observed to be duplicates from the outset and were the first to be pruned. A quick sorting of the themes in Excel spreadsheet reduced them to 66. The sorting also placed related words side by side for easy review and comparison. Each theme was then reviewed and compared with related ones, sorted together and checked for synchrony.

Initial classification was into thirteen major themes: ability, appreciation, awareness, collaboration, application, integration, creativity, communication, evaluation, disciplinary grounding, disciplinary humility, ethics, understanding. Upon closer look, and returning to confirm definitions in literature, there was some back and forth with literature at this stage before components of ability, appreciation, awareness, and application were found to fit into another theme, application went into integration and creativity, while appreciation and awareness were merged into disciplinary grounding and humility. In addition, some themes were found to be clearly disciplinary and were difficult to consider as interdisciplinary, for example critical thinking. Meanwhile, many themes were found to be synonymous and thus merged. Another quick observation was the vagueness (requiring simpler definition or interpretation) of some of the theme and indicators to adequately measure competencies or any concept. Components of themes or themes that were found vague were reframed as the case may be or dropped from the list e.g., "A multidisciplinary approach is needed to find the solution", "Being able to use declarative and procedural knowledge to solve problems". Also observed were the double-barreled indicators that load multiple items into one, e.g., "Gather, manage, and analyze data".

Following the above was the sorting of the indicators to find synchrony and relatedness. Similar observations as with the themes were recorded here too. Understanding of the ethical and legal regulations around OSH issues and problems, recognition of determinants and enablers of OSH challenges, control and prevention of OSH issues and problems were themes that emerged from the exercise with the indicators.

In addition, the themes were compared with the program core syllabi, and the first observation was that themes had to be specific for occupational safety and health and the learning outcomes of the syllabi were strong in evaluations such as "design appropriate research methods", "evaluate the strengths and limitations of epidemiologic reports", "draw appropriate inferences from data, ability to use sound data analysis and evidence-based decision making (interpret and analyze data)"; compliance to OSH laws and regulations and ethics etc. On cursory look, the core syllabi, review shows that interdisciplinary competencies were not specifically or clearly threaded in the learning objectives. Broad themes that could infer interdisciplinarity are prominent and some of the indicators above would easily complement the themes. Some of the broad themes may also incorporate more than one expected competency. Moreso, that almost all of the competencies are complimentary and not exclusive.

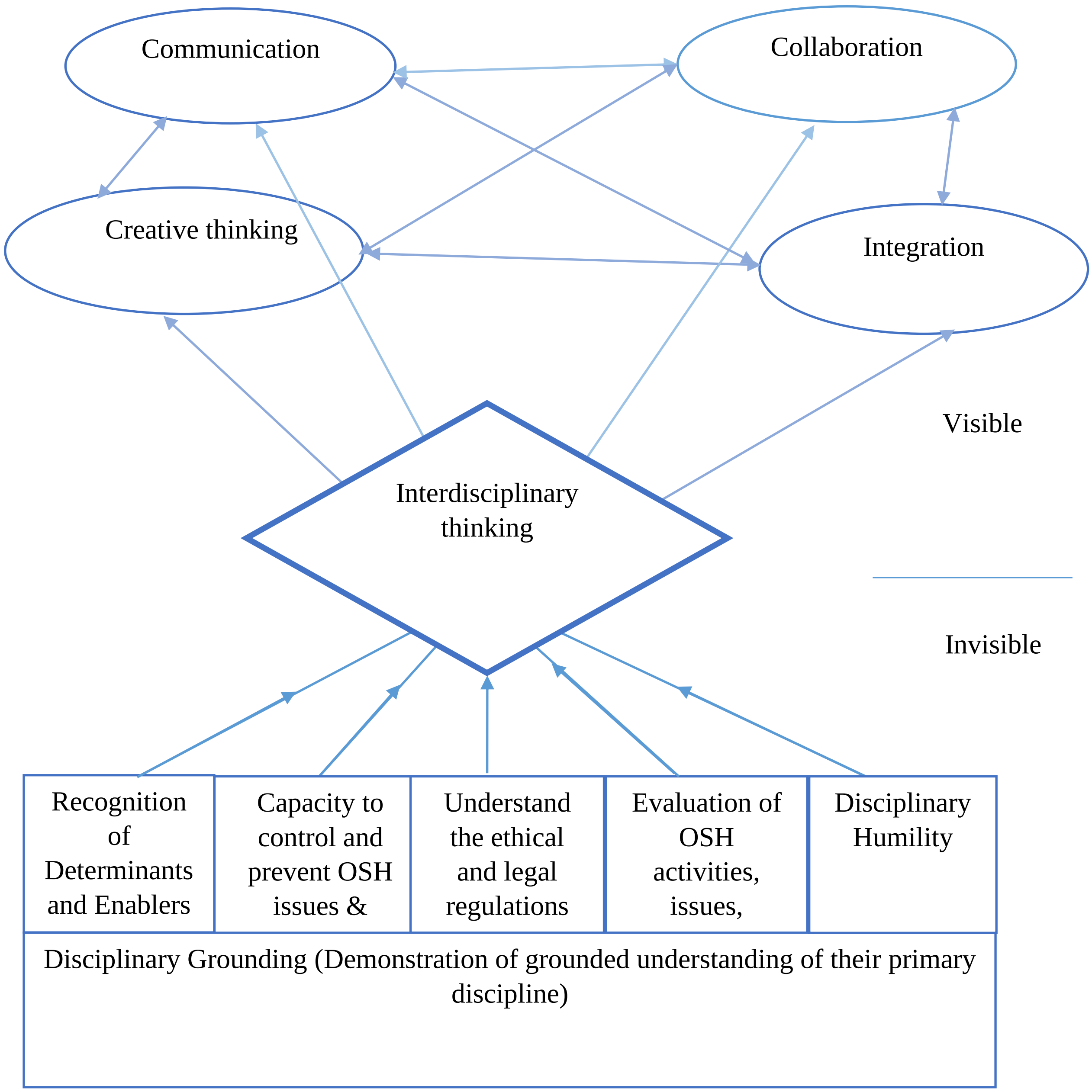
Overall, the interdisciplinary competencies in literature and the core syllabi that emerged are: disciplinary grounding (demonstration of grounded understanding of their primary discipline); recognition of determinants and enablers of OSH challenges; control and prevention of OSH issues and problems; disciplinary humility (recognize and accepts its own limitation to adequately proffer total solution); understand the ethical and legal regulations around OSH issues and problems; evaluate the outcome and outputs of OSH issues and problems; communication; collaboration; integration and creative thinking to apply holistic well-thought out and consulted plan to OSH issues. Table 10 gives detailed qualitative description of expected criteria or indicators of measurement (Olson et al., 2005; Boix Mansilla &

Duraising, 2007; Daud et al., 2010; Newton et al., 2012; Tripp & Shortlidge, 2019; ACOEM, 2020; Ciraldo, 2020).

4.1.1 Interdisciplinary Competency Evaluation Framework in Occupational Safety and Health (iCER-OSH) Framework

In order to adequately respond to what will constitute the components of the rubric to measure interdisciplinary competencies in occupational safety and health and to rally around a focus, this study developed an iCER-OSH framework as a cogent result of the reviews. This framework conceptualizes a complimentary and formative relationship between and within the components of interdisciplinary competencies in OSH as shown in Figure 4.1 (pg. 133). The framework was conceived as a structured layer of interdisciplinary competencies, especially in OSH where each component aggregates into strata (termed visible and invisible section) of build-up on each other. This is likened to the iceberg model of competencies. The first layer is disciplinary grounding, “the degree to which student work is grounded in carefully selected and adequately employed disciplinary insights”. This competency is adjudged by literature and faculty experts as foundational for any interdisciplinary venture (Boix Mansilla & Duraisingh, 2007; Repko, 2008; Borrego et al., 2009; Borrego & Newswander, 2010). It is expected that students did not need to master each of the contributing disciplines but that they do need enough depth to reflect on the nature of disciplines and make meaningful connections. On the above premise, the iCER-OSH framework thus considers disciplinary grounding as the foundation (basic) or first layer on which all interdisciplinary effort must be built and inferring that no

Figure 4.1 The iCER-OSH Framework



interdisciplinary effort can be initiated without this foundation as depicted in Figure 4.1.

Building on this foundation is another layer (level two) of other competencies including recognition of determinants and enablers of OSH; capacity to control and prevent OSH issues & problems; understanding of the ethical and legal regulations around OSH; disciplinary humility; and evaluation of OSH activities, issues, policies and programs. At this level, these competencies can be viewed as core to specific interdisciplinary objectives and thus lend credence to the notion that interdisciplinarity is contextual. These 2 lower layers are conceptualized as the invisible layer of competencies (likened to the submerged and invisible layer of the iceberg model of competencies). Level 2 competencies are specifics individuals must assume before they can adequately function as interdisciplinary competent experts in occupational safety and health. This layer (level 2) and the foundation (Level 1) were termed core by Olson et al (2005). This study extends this notion and presents a model where disciplinary grounding is considered foundational. Level two forms the core layer that informs interdisciplinary thinking. All competency layers below the interdisciplinary thinking are considered invisible and likened to the immersed layer of the competency iceberg. The intermediate stage (Star) conceptualized as interdisciplinary thinking is informed by the contributory influences of the invisible layer and it informs the expression of the emerging competencies from that point. From this intermediate stage emerges the expressive competencies of creative thinking, collaboration, integration, and communication (visible). This is in consonant with Claus & Weise (2019) that “in many incidents behaviors, multiple competencies were involved, which meant that the criteria are not independent but rather a composite that creates good interdisciplinary working behavior". The iCER-OSH therefore hypothesize that layer 1 (foundation of interdisciplinarity) can be generalized to any interdisciplinary endeavor, layer 2 is a mix of competencies that are specific for each endeavor that informs interdisciplinary direction and consequent expression. The mindset informed by this potpourri of competencies is called interdisciplinary thinking. In other words, it is the competencies fostered in level two that ultimately determine and define the interdisciplinary direction and competencies that would be expressed. It should be noted that these competencies are complimentary (cannot be treated in isolation from the others) and can only be considered interdisciplinary in concurrent utility with the others and as an emergent whole (Clark & Wallace, 2015).

The complimentary and interconnectedness of the branching competencies of integration, communication, collaboration and creative thinking as depicted in the iCER-OSH framework implies that all simultaneously and concurrently manifest as interdisciplinary competencies and each would likely be inadequate in isolation to demonstrate interdisciplinarity. In other words, thinking creatively requires some integration of multiple thought lines and disciplines i.e., integration is an integral part of creative thinking, and creativity mindset is required to integrate; so also, is communication a component of collaboration and vice versa. Integration stands as a component and contributory part of this whole because it is a required skills/competence that concentrates on the link between disciplines with weight on understanding how knowledge from each field relates to and inform the others. This study thus postulates that there would be active overlaps between the indicators of the branching competencies from the interdisciplinary thinking intermediate.

All competencies and their indicators were compiled into an item bank of 10 competencies and 81 indicators (Table 10, pg. 114 -116). Proceeding from here, this study was focused on the four competencies that emerged from the interdisciplinary thinking intermediate of the iCER-OSH. The competencies of integration, collaboration, creative thinking, and communication, comprising 34 indicators forms the iCER-OSH rubric utilized to review the 35 capstone projects. Psychometric analysis was therefore limited to the four competencies in the iCER-OSH rubric while layers below the intermediate interdisciplinary thinking in the iCER-OSH framework is therefore suggested for future research.

4.1.2 Expected criteria and indicators of measurement of Interdisciplinary Competencies in OSH

The result of the review of literature reveals the underlisted competencies as relevant to interdisciplinary competencies in OSH.

4.1.2.1 Disciplinary grounding

Disciplinary grounding is a theme first observed from a review of available literature (Boix Mansilla & Duraisingh, 2007; Boix Mansilla et al., 2009: Tripp & Shortlidge, 2019; Tripp & Shortlidge, 2020) and were later confirmed from some of the learning objectives in the core syllabi. It is a demonstration of grounded understanding of the primary discipline of each participant on the CARERC program. The learning objectives in the core syllabi also possess key statements that require foundational competencies in OSH disciplines such as public health, environmental health, or agriculture. A quick example of such would be “communicate inter-professionally regarding study management processes, problem conceptualization, ethics and core public health knowledge”. Most literature rate this as the first competency in order to commence any venture in interdisciplinarity. Boix Mansilla & Duraisingh (2007 p. 222) described it as “the degree to which student work is grounded in carefully selected and adequately employed disciplinary insights”. It would then be the launch pad from which all other competencies build. The indicators (Table 4.1, pg. 140) are evident when capstone projects reveal students written work are current and up to date in a field of practice; the selected disciplinary insights are fit to inform the issue at hand, shows no key disciplinary perspectives are missing, whether or not the work exhibit misconceptions and if the considered theories, examples, findings, methods, and forms of communication employed is in accordance with the disciplinary origins. Also, the indicator can determine if misconceptions around disciplinary issues are identified and clarified. As result of the reviews, this competency is being hypothesized to serve as the foundation for all interdisciplinary work as presented in the iCER-OSH framework in Figure 1.

Table 4.1 Interdisciplinary Competency Evaluation Framework Matrix in OSH (iCER-OSH)

Criteria	**Disciplinary Grounding (demonstrate grounded understanding of their primary discipline)**	**Recognition of determinants and enablers of OSH challenges**	**Control and prevention of OSH issues and problems**	**Disciplinary Humility and thinking (recognize and accepts its own limitation to adequately proffer solution)**	**Understand the ethical and legal regulations around OSH issues and problems**	**Evaluation (impact of OSH issues and problems)**	**Communication (report effectively OSH issues and challenges)**	**Collaboration easily to proffer and creative solutions with other disciplines to design robust OSH solutions**	**Integration**	**Creative thinking (to apply holistic well-thought out and consulted plan to OSH issues)**
Indicators	Stay current in one's field of practice	Recognize the influence of cultural and social factors in occupational health and safety practices	Identify health and safety hazards of work site processes and operations	Easily recognize disciplinary personnel gaps in OSH plans	Know occupational safety and health laws and regulations	Design and initiate research methodology	Communicate effectively with a variety of stakeholders (eg, management, labor)	Function effectively on an interdisciplinary team	Design and deliver adult education programs	Design and initiate research or work process on multiple methods and knowledge sources
	Selected disciplinary insights fit to inform the issue at hand	Demonstrate awareness of diversity in social and cultural beliefs	Identify OSH risks and opportunities	Able to assemble teams of multiple disciplines to resolve OSH issues	Understand the ethical issues around OSH issues	Collect and Gather OSH Data, Manage OSH Data	Able to present idea and opinion in a clear and holistic way	Manage staff/personnel resources effectively	Design and implement changes in the work environment	Design and implement screening programs based on multiple methods and knowledge sources to address a problem
	Any key disciplinary perspectives missing	Understand the relationship between occupational exposures and health outcomes	Assess risks to population health	Demonstrate easy adaptation to broader workplace safety and health issues	Apply the understanding of ethics, laws and regulation in implementation of programs	Analyze simple and comprehensive OSH work/research data	Write well to communicate opinion and issues in a clear and holistic manner	Display effective leadership over multiple team members and activities	Formulate and implement new guidelines and policies	Design and implement surveillance systems from exploring methods complimentary from more than one discipline

Table 4.1 Interdisciplinary Competency Evaluation Framework Matrix in OSH (iCER-OSH) {Continued}

Criteria	**Disciplinary Grounding (demonstrate grounded understanding of their primary discipline)**	**Recognition of determinants and enablers of OSH challenges**	**Control and prevention of OSH issues and problems**	**Disciplinary Humility and thinking (recognize and accepts its own limitation to adequately proffer solution)**	**Understand the ethical and legal regulations around OSH issues and problems**	**Evaluation (impact of OSH issues and problems)**	**Communication (report effectively OSH issues and challenges)**	**Collaboration easily to proffer and creative solutions with other disciplines to design robust OSH solutions**	**Integration**	**Creative thinking (to apply holistic well-thought out and consulted plan to OSH issues)**
Indicators	Are the theories, examples, findings, methods, and forms of communication employed in accordance with their disciplinary origins		Assess opportunities for OSH issues	Seek out diversity of perspective	Identify ethical dilemmas and work in an ethical manner	Interpret and make inferences from OSH Data	Interpret and disseminate policies clearly	Harnesses team's potential for ultimate goal	Create and promote a culture of wellness in the workplace	Design and implement health promotion and education programs
	Does the work exhibit misconceptions?		Easily identify and recognize missing gaps in implementing OSH plans	Easily embrace contradictions	Understand and apply relevant laws and regulations	Apply OSH/scientific Data and findings	Communicate effectively with other safety and health professionals		Demonstrate attention to thoroughly describing the approach for fulfilling interdisciplinary interaction among peers	Design and implement work process interventions built on more than one disciplinary approach

Table 4.1 Interdisciplinary Competency Evaluation Framework Matrix in OSH (iCER-OSH) {Continued}

Criteria	**Disciplinary Grounding (demonstrate grounded understanding of their primary discipline)**	**Recognition of determinants and enablers of OSH challenges**	**Control and prevention of OSH issues and problems**	**Disciplinary Humility and thinking (recognize and accepts its own limitation to adequately proffer solution)**	**Understand the ethical and legal regulations around OSH issues and problems**	**Evaluation (impact of OSH issues and problems)**	**Communication (report effectively OSH issues and challenges)**	**Collaboration easily to proffer and creative solutions with other disciplines to design robust OSH solutions**	**Integration**	**Creative thinking (to apply holistic well-thought out and consulted plan to OSH issues)**
Indicators			Effectively implement multi-task OSH workflow plans	Look for strengths in arguments you dislike and weaknesses in those you like.	Recognize the principles of all other occupational safety and health core and allied disciplines	Measure and make judgement about programs	Identify the overlap among concepts and methods used by disciplines			Develop and implement health and safety programs
						Evaluate programs, policies, and procedures				Apply best practices to optimize adoption and sustainability
										Look for unexamined linkages and unexpected effects in program activities

4.1.2.2 Recognition of determinants and enablers of OSH challenges

The literature review is resplendent with complexities enabling or determining OSH identification, program design, implementation and outcomes (Ocloo et al., 2021). The core syllabi too push for the need for trainees to be able to "demonstrate cultural competency in public health". Any viable OSH venture must commence with an understanding and appreciation of cultural and social factors influencing occupational safety and health. This involves an understanding of the relationship between occupational exposures, social perspectives, and health outcomes. This begins with identifying cultural and social issues that may impact OSH in the capstone project (Table 4.1, pg. 140-142). The capstone project then proceeds to recognize the influence of cultural and social factors in occupational health and safety practices (Olson et al, 2005). Also, it is important to have been the awareness of diversity in culture and social beliefs and their relationships in determining OSH outcomes in the workplace. This in the result of the review commenced the median layer of competencies (a suite of competencies) that informed or contributed to the intermediate interdisciplinary thinking in Figure 1 (pg.135).

4.1.2.3 Control and prevention of OSH issues and problems

A review of available literature revealed that the complexity of the workplace requires a lot of control and prevention efforts that are usually designed with contributions from multiple sources and disciplines in an integrated manner, since the workplace is usually an environment housing diverse and varied specialists, tools and space arrangement working in consonance to achieve a common product. This also makes the environment prone and susceptible to varied occupational hazards. Hence, approaches to control and prevent these hazards must therefore be interdisciplinary (Olson et al., 2005). Approaches to control and prevent hazards must first realize the need for an interdisciplinary outlook to proffer consensus control and prevention plans that would foster the safety of the varied occupation in the environment. Indicators of control and prevention (Table 4.1, pg. 140-142) in this study are: the capstone project identifies health and safety hazards of work site processes and operations, OSH risks and opportunities, assesses these risks and opportunities, identifies and recognizes missing gaps in implementing OSH plans against the risks and for the opportunities, and finally, effectively implements multi-task OSH workflow plans to both mitigate the risk and expand the opportunities. The framework also reveals this as a component complimentary competency of interdisciplinary thinking (Figure 1, pg. 135).

4.1.2.4 Understand the ethical and legal regulations around OSH issues and problems!

This is a state of mind that consciously seeks to interpret and apply a cautionary outlook to ensure that humans and the environments are protected in the application and integration of knowledge to solve problems. The good of all is considered the desired good right from conception to implementation of ideas (Newell et al., 1990; Baxter- Magolda, 2001). It both sets up consensus rules and regulations to guide how issues are resolved (ACOEM, 2020, Daud et al., 2010). Indicators (Table 4.1, pg. 140-142) in this study are: the capstone project reveals it identifies areas of need for the application of regulation/law or ethical considerations, knows, understands and applies occupational safety and health laws and regulations, identifies ethical dilemmas and work in an ethical manner, understand and apply relevant laws and regulations and recognizes the principles of all other occupational safety and health core and allied disciplines. Review results present this also as a complimentary component of interdisciplinary thinking as shown in Figure 1 (pg. 135).

4.1.2.5 Evaluation

Evaluation is the ability to design research methods to measure the effectiveness of program plans, ethical and professional strategies in occupational safety and health. It involves the understanding of the strategies and methods available for evaluation and recognition of their limitations and constraints, including how these affect the plan. In addition, it is a demonstration of systems thinking using epidemiology theory and concepts through data collection, analysis, interpretation, evidence-based reasoning, and judgement (Lattuca et al., 2012). Also, it uses data analysis and research methods based on sound theory and concepts. Evaluation involves appreciating issues associated with study design and research methods for conducting occupational health and safety research. In addition, it could involve reviewing occupational and environmental epidemiologic literature in a systematic and critical manner for assessing disease, injury associations and risk assessment. Capstone projects should reveal (Table 4.1, pg. 140-142) that the student understands the strategies and methods available for evaluation and knows their limitations and constraints. Possessing this skill also means that one can demonstrate the ability to assess and critically review literature in a substantive area of research, be able to identify gaps in knowledge and be able to formulate original research hypotheses or statements (Besterfield-Sacre et al., 2004; Newell & Luckie, 2019). Evaluation also involves judging the strengths and limitations of epidemiologic reports to make viable improvement decisions in OSH. Projects should reveal they draw appropriate inferences from data and demonstrate an understanding of concepts of probability and statistical inference as they apply to problems in public health and OSH. Review results from literature show a strong demand for evaluation competency in interdisciplinary endeavors, though some literature raised the need for development of interdisciplinary methodologies for evaluation (Lattuca et al., 2012). The learning objectives in the core syllabi also reflect a high demand for the graduates to be strong in evaluation competencies with specific clauses like "evaluate program planning, ethical and professional strategies in public health", "identify key sources of data for epidemiologic purposes", calculate basic epidemiologic measures and draw appropriate inferences etc. This competency as shown by the reviews is also a contributory component to the interdisciplinary thinking as reflected in the framework in figure 1 (pg. 135).

4.1.2.6 Disciplinary Humility

This is a disposition characterized by comprehensive exploration of issues, ideas, or events to observe, identify, and point out one's own limitations to offer any resolution without the help from others. Mullally & Byrne (2016) referred to it as the "necessary prerequisite to and basis for authentic transdisciplinary conversations and transcendent knowledge generation". It is the habit of the mind (Newell & Luckie, 2019) to recognize and accept own limitation to adequately proffer total solution to issues. “It is developing a mindset, or epistemic perspective, that is infused with humility, inclusivity, and respect for other disciplinary epistemologies” (Peterson et al., 2010, Byrne & Mullally, 2016; Tripp & Shortlidge, 2019; Dammann, 2020). Byrne et al., (2023) argued for an input that “not just feeds into the disconnect between respective disciplinary approaches”, but one that rather highlights the need for journeying together with ‘disciplinary humility’, as equal partners. Indicators emerging from literature in this study are (Table 4.1, pg. 140-142): the capstone project easily recognize disciplinary personnel gaps in OSH plans, can assemble teams of multiple disciplines to resolve OSH issues, demonstrate easy adaptation to broader workplace safety and health issues, seek out diversity of perspectives, easily embrace contradictions and look for strengths in arguments author dislike and weaknesses in those they like. Results from review of literature show it is contributory and complimentary with the other competencies to inform an interdisciplinary thinking as observed in the iCER-OSH framework (Figure 1, pg. 135).

4.1.2.7 Interdisciplinary Thinking

Interdisciplinary thinking is the intermediate medium hypothesized by the iCER-OSH framework (Figure 1, pg. 135). This medium could be viewed as a suite or potpourri of competencies that informs a mind disposition to reflect on approaching task from a perspective that holistically looks at multiple ways and methodology to resolve the attending issues. A suggested way to “facilitate this kind of interdisciplinary thinking is to construct stories that encourage comparisons of divergent perspectives, purposefully painted in their extremes” (Lawrence, 2011).

The result as depicted in the iCER-OSH framework (Figure 1) presents five other competencies contributing to this mindset from where more expressive competencies emerged. “Interdisciplinary thinking presents a concept of intersubjectivity which views the real world and tasks as evolving/emergent multi-faceted phenomena” (Dreyfuss et al., 2011). Spelt et al., (2015) called this “the ability to integrate or synthesize knowledge of disciplines” and agrees with Klein (2010) that it is “the blending of knowledge that enables the integration of disciplinary knowledge and allows an advance in understanding”. It is a locus point where competencies converge, remold, and emerge with interdisciplinary flavors.

4.1.2.8 Communication

Interdisciplinary Communication was defined as the crucial ability to be “open minded and non-judgmental in listening to and presenting to, trying to understand other’s perspectives” across disciplines by looking beyond differences in terminology and identifying the overlap among concepts and methods used by disciplines (Stein, 2007; Claus & Weise, 2019; Blom et al., 2021). Interdisciplinarians help promote unity and understanding through effective written and verbal communication (Ciraldo, 2020). It could start with a flexible adjustment to different audiences, bringing stakeholders on board, translating between disciplines, having patience in explaining, simplifying complex and abstract issues, and not forcing own opinion on others. It can also be viewed as ability to write well to communicate opinion and issues in a clear and holistic manner across disciplinary barriers, interpret and disseminate policies clearly, passing information effectively with and between other safety and health professionals, or identify the overlap among concepts and methods used by disciplines (Claus & Weise, 2019). The learning objectives in the core syllabi are also clear in the requirement that learners must develop competence in communication across disciplinary boundaries with clauses like “Generate evidence-based communication for professionalism, advocacy and leadership within core public health areas”, “Communicate inter-professionally regarding study management processes, problem conceptualization, ethics”. The above are reflected in Table 4.1 (pg. 140-142). It can be inferred from the reviews that this builds upon or emerges from interdisciplinary thinking.

4.1.2.9 Collaboration

A behavior controlled by individuals to put effort into team tasks, collaboration manifests in the manner of interacting with other people on the team. It is measured by the quantity and quality of contributions individuals make to team discussions (VALUE ®). Bronstein (2003) has described a model consisting of five components that constitute interdisciplinary collaboration between social workers and other professionals: interdependence, newly created professional activities, flexibility, collective ownership of goals, and reflection on process. Also, Petri in 2010 described necessary elements to make an interdisciplinary collaboration successful: interprofessional education, role awareness, interpersonal relationship skills, deliberate action, and support. The above stems from the humble realization of the need for others to complement specific gaps in a piece of work to make it whole. The assumption here is therefore that a work sample demonstrates the contribution of the student as a complimentary input to the team’s overall output and could span a continuum from mild to dominant (Stein, 2007; Fewster-Thuente et al., 2008; Claus

& Weise, 2019; Newell & Luckie, 2019; Tripp & Shortlidge, 2019). Indicators of this criteria in OSH (Table 4.1, pg. 140-142) are individuals' unique disciplinary contribution to team objectives at meeting, facilitation of the contributions of other team members, individual's contributions outside of team meetings, how the individual fosters constructive team climates and the person's response to conflict. It is also evident in how effectively a person function in interdisciplinary team, how s/he manages staff/personnel resources effectively, and how effectively the individual displays leadership over multiple team members and activities and harnesses team's potential for ultimate group goal (Olson et al., 2005). This study also ambitiously assumed collaboration when data are incorporated from multiple disciplines and especially when secondary data are being used. Review results show that this competency emerges from interdisciplinary thinking as reflected in Figure 1 (pg.135) and indicators are presented in Table 10 (pg. 140-142).

4.1.2.10 Integration

This is the most mentioned requirement of interdisciplinarity in literature despite being a challenging concept to measure (Repko, 2008; Mentkowski & Sharkey, 2011; Repko & Szostak, 2016; Tripp & Shortlidge, 2019; Tripp & Shortlidge, 2020; Davidesco & Tanner, 2020). Integration is a perception or inclination learners develops across curriculum and disciplines that enables simple connections of ideas and experiences from multiple disciplines to synthesize and transfer learning or tasks to produce cognitive advancement like solving a problem, designing new methodology or writing a new procedure or scheme. Ideally, learners' garners from previous and current learning experiences and other disciplinary boundaries and synchronize and design a significantly different knowledge from those backgrounds, possibly initiating or situating another discipline or cognitive advancement (Boix Mansilla & Duraising, 2007; VALUE®). This is also an ability to pull concepts together from other disciplines to proffer integrated and creative solutions to OSH challenges (Olson et al., 2005). Criteria and indicators (Table 4.1, pg. 140-142) of integration are the ability to connect to prior experience, connect relevant experience and academic knowledge, connect to discipline (see/make connections across disciplines, perspectives), transfer by adapting and applying skills, abilities, theories, or methodologies gained in one situation to new situations, integrated communication reflect and self-assess (demonstrates a developing sense of self as a learner, building on prior experiences to respond to new and challenging contexts which may be evident in self-assessment, reflective, or creative work). This study assumes that integration includes utilization and incorporation of data from more than one discipline and methodologies. The reviews also show that this is an offshoot of interdisciplinary thinking as reflected in the framework in figure 1 (pg. 135).

4.1.2.11 Creative thinking

Creative thinking is both the capacity to combine or synthesize existing ideas, images, or expertise in original ways and the experience of thinking, reacting, and working in an imaginative way characterized by a high degree of innovation, divergent thinking, and risk taking (VALUE®). It can also be seen in this context as reflective thinking to apply holistic well-thought out, unconventional thinking (Blom et al., 2021) and consulted plan to OSH issues; design and initiate research or work process on multiple methods and knowledge sources; design and implement screening programs based on multiple methods and knowledge sources to address a problem; design and implement surveillance systems from exploring methods complimentary from more than one discipline; design and implement health promotion and education programs; design and implement work process interventions built on more than one disciplinary approach; develop and implement health and safety programs; apply best practices to optimize adoption and sustainability and look for unexamined linkages and unexpected effects in program activities. Review results reveal that this is usually a product of interdisciplinary thinking as reflected in the iCER-OSH framework (Figure 4.1, pg. 135) and its indicators are presented in Table 10 (pg. 140-142).

4.1.3 Determine the components of the Rubric to measure interdisciplinary competencies in Occupational Safety and Health

The first step to respond to the above question was to determine the components of the Rubric to measure interdisciplinary competencies in Occupational Safety and Health. The principle of constructive alignment was utilized to develop a framework of interdisciplinary competence criteria in which intended learning outcomes (indicators), teaching methods, assessment and evaluation are all interdependent and only by truly integrating these components together, do we ensure student learning as is being evaluated by this study. Based on literature (Tripp & Shortlidge, 2020) an ICER-OSH framework was designed (Figure 1) which rests on a non-compensatory relationship between the criteria that comprises the competencies. The ICER-OSH framework suggests that since disciplinary grounding appears to be the foundational competency in interdisciplinarity (Klein & Newell 1998; Boix Mansilla & Duraisingh, 2007; Repko (2008; Borrego et al., 2009; Borrego & Newswander, 2010), it could serve as the bedrock competency on which all the other competencies are built. Four other competencies around recognition, capacity and understanding are built on this foundational disciplinary grounding to become OSH competent. The last four competencies are demonstrations of an OSH competent individual or visible components/evidence of an OSH competent professional and emergent from a disciplinary thinking intermediate.

Building on the above framework and the expected competencies as reflected in Table 4.1 and Figure 1. Table 4.1 presents the ICER-OSH rubric with 10 expected interdisciplinary competencies criteria and 81 indicator items developed from the various indicators that comprise each competence in OSH. The dichotomous rubric is designed to evaluate if the competence is “present” as “one” and “not present” as “zero”.

4.1.3.1 Instrument modification

In the process of the capstone review, about 8 items of the iCER-OSH instrument were modified for grammar or expanded or split to better capture the presence of the competencies. Grammar edits were also taken as seriously as splitting and unpacking modifications of double-barreled or outright additions of fresh indicator as reflected in Table 4.2. Item 1e (The capstone project identified misconceptions in) was an incomplete and hanging statement that was completed as (The capstone project identified misconceptions surrounding the idea); and in 8c (The capstone project reveals it displayed effective leadership over multiple team members/activities) “where” and “was” were removed between members and activities to remove the tendency to interrogate members and activities as separate items within one item. The author added items 7g (The capstone project reveals it incorporated data from more than one disciplines); 7h {The capstone project reveals it offered recommendations for future intervention(s)}; 8f (The capstone project reveals it incorporated data from more than one sources); 8g (The capstone reveals it utilized secondary data); and 9j (The capstone project reveals it implemented health and safety programs) as those items reflected some forms of indicators in the authors perspective and interpretation of literature and were more relevant to capstone projects in the program than most other indicators on the item. Item 9k {The capstone project reveals it applied best practices to optimize sustainable activity(ies) plan} was modified to be clearer in what it set out to measure. Items from this stage were shared with the members of the advisory committee for review and validation before proceeding to utilize for the review of capstones.

Table 4.2 Details of the items of iCER-OSH Rubric

	Criteria and indicators	Response	
S/N	**Item**	**Yes**	**No**
1	**Demonstrate grounded understanding of their primary discipline**		
a	The capstone project demonstrates current knowledge in its contributory fields of practice		
b	The capstone project demonstrates a disciplinary insight fit to inform the issue at hand		
c	The capstone project is missing (some) key disciplinary perspectives		
d	The theoretical concept used in the capstone project fit the contributory disciplines.		
e	The capstone project identified misconceptions surrounding the idea		
f	The capstone project clarified identified misconceptions		
2	**Recognition of determinants and enablers of OSH challenges**		
a	The capstone project recognizes the influence of cultural factors in occupational health and safety practices		
b	The capstone project recognizes the influence of social factors in occupational health and safety practices		
c	The capstone project demonstrates awareness of diversity in social belief		
d	The capstone project demonstrates awareness of diversity in cultural belief		
e	The capstone project reflects understanding of the relationship between occupational exposures and health outcomes		
3	**Control and prevention of OSH issues and problems**		
a	The capstone project identified health and safety hazards of work site operations		
b	The capstone project identified health and safety hazards of work site processes		
c	The capstone project identifies OSH risks		
d	The capstone project identifies OSH opportunities		

Table 4.2 Details of the items of iCER-OSH Rubric (Continued)

	Criteria and indicators	Response	
S/N	Item	Yes	No
e	The capstone project assesses the OSH risks		
f	The capstone project assesses the OSH opportunities		
g	The capstone project identifies missing gaps in implementing OSH risk mitigation plans		
h	The capstone project identifies missing gaps in implementing OSH opportunities expansion plans		
i	The capstone project effectively implements multi-task OSH workflow plans		
4	**Recognize and accepts its own limitation to adequately proffer solution**		
a	The capstone project easily recognizes disciplinary knowledge gaps in OSH plans		
b	The capstone project reveals assemblage of teams of multiple disciplines to resolve OSH issues		
c	The capstone project demonstrates its activities are easily adaptable to broader workplace safety and health issues		
d	The capstone project reveals it sought out diversity of perspective?		
e	The capstone project reveals it embraced contradiction of arguments?		
f	The capstone project reveals it looked for strengths in arguments the author(s) disliked.		
g	The capstone project reveals it looked for weaknesses in arguments the author(s) liked		
5	**Understand the ethical and legal regulations around OSH issues and problems**		
a	The capstone project reveals it identifies areas of need for application of regulation/law		
b	The capstone project reveals it identifies areas of need for application of ethical consideration		
c	The capstone project reveals it knows occupational safety and health laws/regulations		
d	The capstone project reveal it understands the ethical regulation around OSH		

Table 4.2 Details of the items of iCER-OSH Rubric (Continued)

	Criteria and indicators	Response	
S/N	Item	Yes	No
e	The capstone project reveals it identified ethical concerns in the implementation of its plans		
f	The capstone project reveals it complied with OSH ethics in the implementation of its plans		
g	The capstone project reveals it complied with OSH laws in the implementation of its plans		
h	The capstone project reveals it managed financial resources effectively for the OSH project		
6	**Evaluation**		
a	The capstone reveals it designed a research method for the project		
b	The capstone indicates it identifies the limitations of the method used		
c	The capstone project reveals it identifies OSH Data		
d	The capstone project reveals it collected OSH Data		
e	The capstone project reveals it managed OSH Data		
f	The capstone project reveals it analyzed OSH data		
g	The capstone project reveals it interpreted OSH Data		
h	The capstone project reveals it made inferences from OSH Data		
i	The capstone project reveals it used the inferences from OSH data to inform decision making		
j	The capstone project reveals it made judgement about OSH programs using data		
k	The capstone project reveals it made judgement about OSH policies using data		
l	The capstone project reveals it made judgement about OSH procedures using data		

Table 4.2 Details of the items of iCER-OSH Rubric (Continued)

	Criteria and indicators	**Response**	
S/N	**Item**	**Yes**	**No**
7	**Integration**		
a	The capstone project reveals it is designed to reflect consideration of relevant activities based on multiple methods		
b	The capstone project reveals it is designed to implement new health promotion processes based on multiple methods		
c	The capstone project reveals it formulated new guideline(s) based on multiple methods		
d	The capstone project reveals it formulated new policy(ies) based on multiple methods		
e	The capstone project reveals it created a new culture of wellness in the workplace based on multiple methods		
f	The capstone project reveals it created a new surveillance process in the workplace based on multiple methods		
g	The capstone project reveals it incorporated data from more than one disciplines		
h	The capstone project reveals it offered recommendations for future intervention(s)		
8	**Collaboration**		
a	The capstone project reveals it identified specific personnel gap in the execution of the project		
b	The capstone project reveals it managed staff/personnel resources used in the project effectively		
c	The capstone project reveals it displayed effective leadership over multiple team members/activities		
d	The capstone project reveals it functioned effectively on a team of more than one disciplines		
e	The capstone project reveals it demonstrated attention to thoroughly describing the approach for fulfilling work interaction among peers		
f	The capstone project reveals it incorporated data from more than one sources		
g	The capstone reveals it utilized secondary data		

Table 4.2 Details of the items of iCER-OSH Rubric (Continued)

	Criteria and indicators	Response	
S/N	**Item**	**Yes**	**No**
9	**Creative Thinking**		
a	The capstone project reveals it designed project activities on multiple methods		
b	The capstone project reveals it implemented project activities on multiple methods		
c	The capstone project reveals it designed screening activities based on multiple methods		
d	The capstone project reveals it implemented screening activities based on multiple methods		
e	The capstone project reveals it designed surveillance activities based on multiple methods		
f	The capstone project reveals it implemented surveillance activities based on multiple methods		
g	The capstone project reveals it implemented a well-designed health promotion and education programs		
h	The capstone project reveals it implemented a well-designed work process interventions built on more than one disciplinary approach		
i	The capstone project reveals it developed health and safety programs		
j	The capstone project reveals it implemented health and safety programs		
k	The capstone project reveals it applied best practices to optimize sustainable activity(ies) plan		
l	The capstone project reveals it looked for unexamined linkages in project activities		
m	The capstone project reveals it looked for unexpected effects in project activities		
10	**Communication**		
a	The capstone project demonstrates that it communicates effectively with a variety of stakeholders (e.g., management, labor)		
b	The OSH opinion presented in the capstone project is clear to understanding		
c	The capstone project demonstrates that it writes well to pass its opinion in a concise way		

Table 4.2 Details of the items of iCER-OSH Rubric (Continued)

	Criteria and indicators	Response	
S/N	Item	Yes	No
c	The capstone project demonstrates that it writes well to pass its opinion in a concise way		
d	The capstone project demonstrates that it interprets policies clearly		
e	The capstone project demonstrates that it disseminates policies clearly		
f	The capstone project demonstrates that it discusses effectively with other safety and health professionals		

4.1.4 Results of “Presence” or “Not present” of Interdisciplinary Competencies in OSH in the CARERC capstone projects

Following the literature reviews, 35 submitted capstone projects were reviewed using the dichotomous iCER-OSH instrument (Table 11) developed to confirm the “Presence” or "Not present” of the expected interdisciplinary competencies in the capstone projects. It was at this level that the decision was made to focus the application of the instrument on reviewing only the four competencies emerging from interdisciplinary thinking viz: integration, collaboration, creative thinking, and communication. Result of percentage of “Presence” or “Not present” of the competencies in the capstone projects are stated below:

4.1.4.1 Integration

This competency has eight indicators and analysis of presence of indicators reveals the following: Percentage of presence coded as “Yes” and otherwise of indicators of integration competency are presented in Table 4.3 below:

Results of the review of capstones with the iCER-OSH rubric show that 83% of the capstone project considered the design of many of its activities based on multiple methods (Table 4.3). Indicators of integration like design of implementation programs in health promotion, formulation of new guidelines/ policies, creation of new cultures of wellness /surveillance processes or products based on multiple methods, were predominantly absent in the capstones (Table 4.3). However, about 83% of capstones incorporated data from more than one discipline in a way that integrated the data to address one purpose of health in the workplace (Table 4.3) and all capstones offered viable recommendations for future interventions (Table 4.3). Almost all capstone projects were focused on identifying problems, or the prevalence or state of the problems, and analyzing those problems. None or few had reported on providing programmed solutions or interventions to the OSH problems (All have concluded with recommendations for future research or intervention).

Table 4.3 Percentage of "Presence" or "Not" of indicators of Integration

S/N	Item	% Presence	
	Integration	**Yes**	**No**
a	The capstone project reveals it is designed to reflect consideration of relevant activities based on multiple methods	82.90	8.60
b	The capstone project reveals it is designed to implement new health promotion processes based on multiple methods	5.70	94.30
c	The capstone project reveals it formulated new guideline(s) based on multiple methods	0.00	100.00
d	The capstone project reveals it formulated new policy(ies) based on multiple methods	5.70	94.30
e	The capstone project reveals it created a new culture of wellness in the workplace based on multiple methods	0.00	100.00
f	The capstone project reveals it created a new surveillance process in the workplace based on multiple methods	2.90	97.10
g	The capstone project reveals it incorporated data from more than one disciplines	82.90	17.10
h	The capstone project reveals it offered recommendations for future intervention(s)	100.00	0.00

4.1.4.2 Collaboration

This competency has seven indicators and analysis of presence of indicators reveals the following: Percentage of presence coded as “Yes” and otherwise of indicators of collaboration competencies is presented in Table 4.4 below:

Results of the review of capstones with the iCER-OSH rubric shows that only about 26% of capstones reported or indicated that they identified specific personnel gaps in the execution of their projects, about 9% of capstones reported or indicated that it managed staff/personnel resources used in the project, 5.7% reported they displayed leadership over multiple team members/activities, 11.4% indicated they functioned effectively in a team of more than one discipline, 14.3% indicated it committed attention to thoroughly describe approach for fulfilling work interaction among peers, 88.6% reported incorporating data from more than one sources and 82.90% reported using secondary data. These results are presented in Table 4.4.

Table 4.4 Percentage of “Presence” or “Not” of indicators of Collaboration

	Item	% Presence	
	Collaboration	**Yes**	**No**
a	The capstone project reveals it identified specific personnel gap in the execution of the project	25.7	74.30
b	The capstone project reveals it managed staff/personnel resources used in the project effectively	8.60	91.40
c	The capstone project reveals it displayed effective leadership over multiple team members/activities	5.70	94.30
d	The capstone project reveals it functioned effectively on a team of more than one disciplines	11.40	88.60
e	The capstone project reveals it demonstrated attention to thoroughly describing the approach for fulfilling work interaction among peers	14.30	85.70
f	The capstone project reveals it incorporated data from more than one sources	88.60	11.40
g	The capstone reveals it utilized secondary data	82.90	17.10

4.1.4.3 Creative Thinking

This competency has thirteen indicators and analysis of presence of indicators reveals the following: Percentage of presence coded as "Yes" and otherwise of indicators of Creative Thinking competencies is presented in Table 4.5 below:

Results of the review of capstones with the iCER-OSH rubric shows that 71.4% of capstones indicated project activities were designed on multiple methods, 88.6% implemented project activities on multiple methods, 51.4% designed screening activities based on multiple methods, 42.9% implemented screening activities based on multiple methods, 22.9% designed surveillance activities based on multiple methods, 17.1% implemented surveillance activities based on multiple methods, 2.9% implemented a well-designed health promotion and education programs, 5.7% implemented a well-designed work process interventions built on more than one disciplinary approach, 5.7% developed health and safety programs, 11.4% implemented health and safety programs, 22.9% applied best practices to optimize sustainable activity(ies) plan, and 100% look for both unexamined linkages and unexpected effects in projects activities respectively.

Table 4.5 Percentage of "Presence" or "Not" of indicators of Creative Thinking

	Item	% Presence	
	Creative Thinking	**Yes**	**No**
a	The capstone project reveals it designed project activities on multiple methods	71.40	28.60
b	The capstone project reveals it implemented project activities on multiple methods	88.60	11.40
c	The capstone project reveals it designed screening activities based on multiple methods	51.40	48.60
d	The capstone project reveals it implemented screening activities based on multiple methods	42.90	57.10
e	The capstone project reveals it designed surveillance activities based on multiple methods	22.90	77.10
f	The capstone project reveals it implemented surveillance activities based on multiple methods	17.10	82.90
g	The capstone project reveals it implemented a well-designed health promotion and education program	2.90	97.10
h	The capstone project reveals it implemented a well-designed work process interventions built on more than one disciplinary approach	5.70	94.30
i	The capstone project reveals it developed health and safety programs	5.70	94.30
j	The capstone project reveals it implemented health and safety programs	11.40	88.60
k	The capstone project reveals it applied best practices to optimize sustainable activity(ies) plan	22.90	77.10
l	The capstone project reveals it looked for unexamined linkages in project activities	100.00	0.00
m	The capstone project reveals it looked for unexpected effects in project activities	100.00	0.00

4.1.4.4 Communication

This competency has six indicators and analysis of presence of indicators reveals the following: Percentage of presence coded as “Yes” and otherwise of indicators of Communication competencies is presented in Table 4.6 below:

Results of the review of capstones with the iCER-OSH rubric shows that disciplinary communication indicators like writing well and clearly and interpreting policies well were present in students’ capstones whereas interdisciplinary communication indicators like interaction with professional of other disciplines (77.10%) to execute tasks in the capstone were found absent in 77.10% of capstone project reports. Overall, the primary construct of interest in this study is interdisciplinary competencies in occupational safety and health.

Table 4.6 Percentage of “Presence” or “Not” of indicators of Communication

	Item	% Presence	
	Communication	**Yes**	**No**
a	The capstone project demonstrates that it communicates effectively with a variety of stakeholders (e.g, management, labor)	22.90	77.10
b	The OSH opinion presented in the capstone project is clear to understanding	100.00	0.00
c	The capstone project demonstrates that it writes well to pass its opinion in a concise way	100.00	0.00
d	The capstone project demonstrates that it interprets policies clearly	100.00	0.00
e	The capstone project demonstrates that it disseminates policies clearly	100.00	0.00
f	The capstone project demonstrates that it discusses effectively with other safety and health professionals	22.90	77.10

4.2 Research Question Two

What are the psychometric properties of the developed interdisciplinary competency assessment Rubric?

Another goal of this study was to develop a calibrated item scale for evaluating interdisciplinary competencies in occupational safety and health. Rasch analysis was applied to dichotomous scale data checking the presence of interdisciplinary competencies in occupational safety and health from the written capstone project of graduates of the CARERC program. Rasch analysis explores the performance of each individual item rather than the total test score and its explorations are rested on the assumption that the presence of an indicator depends only on the difficulty of the item and the subject's ability. The psychometric properties in this section were focused on the four complimentary interdisciplinary competencies of Integration, Collaboration, Communication, and Creative thinking while that of the other six competencies are suggested for further studies. All analyses were executed by the partial credit model which allowed each item to display individual rating scale step calibrations. For the Rasch model to hold, persons and items was scaled along a single linear latent continuum (interdisciplinary competencies in OSH), especially given that unidimensionality is a cogent parameter that cannot be ignored in test theory (Forkmann et al., 2009). For this study, an item calibration plan included evaluation of separation, reliability and Rasch model fit; evaluation of dimensionality and local independence; item spread with re-consideration of separation, reliability and item fit on the total study sample; and individual item characteristics as presented by the wright map.

4.2.1 Evaluation of separation, reliability and Rasch model fit

All analyses were conducted on the calibration sample (n = 35) and the four interdisciplinary competencies of Integration, Collaboration, Communication and Creative thinking in OSH with 34 items. Details of analysis are presented below:

4.2.2 Separation and Reliability

“To ascertain the direction and meaning of the latent variable, there must be sufficient separation in difficulty of the items. Item and person separation indices estimate the spread or separation of persons and items on the measured variable” (Forkmann et al., 2009). Based on Rasch measurement model approach, the acceptable reliability Cronbach's Alpha (α) is between 0.71- 0.99 where it is at the best level (71% - 99%) (Bond et al., 2007). Reliability was evaluated using the indices provided by Winsteps 5.3.2: person separation index, person reliability, item separation, and item reliability. The reliability reports show how reproducible the person and item measure orders (i.e., their locations on the continuum) are (Linacre, 2012). A person separation index of 1.5 or a person reliability coefficient of 0.7 represent an acceptable level of separation and is considered the minimum required to divide the sample into two distinct strata i.e., low and high ability (Wjr, 2015). A person separation index of 2.0 and a person reliability of 0.8 represent a good level of separation and are considered the minimum preferable values (Linacre, 2012).

Validity on the other hand requires more investigation, nonetheless, the empirical assessment of the instrument's ability to distinguish between groups that it should theoretically be able to view as distinct offers some explanation (Trochim, 2003). Essentially, the idea is to start with two groups that have differences and to demonstrate whether the instrument is able to significantly measure those differences (Wolfe & Haynes, 2003; Trochim, 2003). Table 4.7 shows the result of separation and reliability of both person and item. On the basis of 34 items, item separation (3.52) and item reliability (0.93) as well as person separation (2.11) and person reliability (0.82) were very good. The person separation index of 2.11 thus offers preliminary evidence of validity. These values are considered good and clearly exceeded critical values. Results indicate that the item pool defined at least 2 strata of persons' ability and approximately 4 strata of items' difficulty.

Table 4.7 Reliability Characteristics of the 34 Review items

	Item	Person
Reliability	0.93	0.82
Separation	3.52	2.11

4.2.3 Rasch Model Fit

Infit MS, the ratio between observed and predicted variance, was used to examine Rasch model fit of each item. It is the in-lier sensitive quality control statistics, indicating a range in which items are expected to function, items beyond this range are counted as unfit. The expected value for mean square (MNSQ) is approximately 1.0, and values between 0.5 and 1.5 are considered productive for measurement (Linacre, 2012). If the MNSQ value is beyond this range, Z-Standardized Scores (ZSTD) must be checked; ZSTD values of 2.0 or more indicate statistically significant model misfit. Baghaei in his own argument suggested that the unusual response patterns that mislead the analysis and are defined as signs of construct irrelevant variance and multidimensionality (Baghaei, 2008) are shown by values larger than 1.40. Values smaller than 0.60 do not mislead the analysis since they display redundancy of information. They can lead to false high reliabilities (Tabatabaee-Yazdi et al., 2018). However, this study adopted the Linacre's limit of 0.5 and 1.5. "The ideal infit MS value is 1.0 (i.e., observed variance = predicted variance), but limited unexpected variance is allowed" (Forkmann et al., 2009). In this study, because the items were rated using a dichotomous scale, an item with more than 50% unexpected variance than the model predicted (i.e., infit MS > 1.5) was considered as misfitting. A misfitting item could infer a different dimension or may not discriminate appropriately between participants. Items exceeding the above criterion were taken as noisy to the model and thus removed. The remaining items were re-calibrated. This study was careful not to remove too many items in order not to significantly alter the meaning of the underlying construct of interdisciplinary competencies in OSH. Omission of misfits was sustained until a reasonable total fit was attained.

The Rasch model fit was examined on the calibration sample (n=35). Out of the 34 items, 7 had to be excluded because of insufficient model fit (item infit 0.5 < MS > 1.5). Serial removal of items commenced with Collaboration item g (The capstone reveals it utilized secondary data) with Infit MNSQ value of 1.71. Separation values for item and person at this level were 3.52 and 2.11, while reliability for item and person were 0.93 and 0.82 respectively. Following the removal of the Collaboration item g, separation values for item and person were 3.74 and 2.19, while reliability for item and person were 0.93 and 0.83 respectively. With the removal of this item, infit statistics improved and three more items did not fall within acceptable range instead of four items prior to the removal. Next was the removal of Creative item k {The capstone project reveals it applied best practices to optimize sustainable activity(ies) plan}, with Infit MNSQ value of 1.65. Separation values for item and person were 3.08 and 3.37, while reliability for item and person were 0.90 and 0.92 respectively. All item Infit MNSQ values fall within range after this removal of item Collaboration item e. Other removals and detailed statistics are presented in Table 17. Beyond the removal of Collaboration item e, fit statistics fell within range for all except one (Integration item g) with Infit MNSQ value of 0.45, this item Integ_g (The capstone project reveals it incorporated data from more than one disciplines) would have been retained so as to be careful not to remove too many items in order not to significantly alter the meaning of the underlying construct of interdisciplinary competencies in OSH. However, ZSTD was also 2.02 which is slightly above the acceptable value of 2.0, hence, the item was excluded. After its removal, all fit statistics for the remaining item fell within acceptable range. Table 4.9 shows the final fit statistics following the serial removal of unfit items. Results also show that some 9 items were constantly with minimum and maximum measures.

Table 4.8 shows comparative separation and reliability indices following the serial removal of infit items. It commenced with indices for the initial 34 items prior to the serial deletion of unfit items. Item reliability varied between 0.93 and 0.94 and was considered good through serial deletion while person reliability ranged from 0.82, peaked at 0.85 and finally declined to 0.69. Separation indices for items varied between 3.52, peaked at 4.00 and dropped to 3.54 while person separation varied between 2.34 and 1.51. These values are considered good and clearly exceeded critical values. Results indicate about 2 strata of persons' ability and 4 strata of items' difficulty. Table 19 list the items that were excluded for model fit while Table 18 list the remaining fit items with their corresponding statistics.

Table 4.8 Comparative Reliability and Separation statistics for serial removal of unfit items

	Reliability		Separation		infit		Outfit	
Operation	**Item**	**Person**	**Item**	**Person**	**Item MNSQ**	**Person MNSQ**	**Item MNSQ**	**Person MNSQ**
Total items	0.93	0.82	3.52	2.11	0.90	0.93	1.44	1.36
Total items without Collab_g	0.93	0.83	3.74	2.19	0.88	0.93	1.41	1.30
Total items without Collab_g & Creative_k	0.94	0.85	4.00	2.34	0.89	0.91	1.27	1.14
Total items without Collab_g, Creative_k & Collab_f	0.94	0.82	3.89	2.15	0.90	0.92	1.23	1.07
Total items without Collab_g, Creative_k, Collab_f & Creative_b	0.93	0.78	3.75	1.90	0.90	0.93	1.17	1.11
Total items without Collab_g, Creative_k, Collab_f Creative_b & Collab_e	0.93	0.77	3.71	1.82	0.91	0.94	1.15	1.08
Total items without Collab_g, Creative_k, Collab_f Creative_b Collab_e & Integ_g	0.93	0.69	3.54	1.51	0.92	0.94	0.91	0.91

Table 4.8 above shows the list and sequence of removal of misfit items and the resulting fits statistics following each removal of the misfit. Six items were found to be misfitting as shown in Table 4.8. Following the above serial removal of misfit items, Table 4.9 below shows the resulting fit instrument comprising 19 items and their fit properties arranged in order of their difficulty. Indicators of integration and creative thinking appears at the top indicating higher difficulty.

Table 4.9 Item Characteristics of the 19 Items of the Final Item Bank in order of difficulty

						Infit		Outfit	
S/N	Item identity	Item	δi	Measure	SEM	MNSQ	ZSTD	MNSQ	ZSTD
1	Integ_a	The capstone project reveal it is designed to reflect consideration of relevant activities based on multiple methods	-4.51	-5.93	0.65	0.95	0.03	0.77	0.15
2	Creative_a	The capstone project reveals it designed project activities on multiple methods	-3.97	-4.01	0.45	1.12	0.57	0.8	0.04
3	Creative_c	The capstone project reveals it designed screening activities based on multiple methods	-3.53	-2.71	0.42	1.02	0.15	3.56	3.24
4	Creative_d	The capstone project reveals it implemented screening activities based on multiple methods	-3.44	-2.16	0.43	1.00	0.09	2.27	2.14
5	Colab_a	The capstone project reveals it identified specific personnel gap in the execution of the project	-3.35	-0.88	0.51	0.61	-1.4	0.34	-1.03
6	Comm_a	The capstone project demonstrate that it communicates effectively with a variety of stakeholders (e.g, management, labor)	-3.10	-0.61	0.53	0.90	-0.2	3.5	2.19
7	Comm_f	The capstone project demonstrate that it discusses effectively with other safety and health professionals	-3.05	-0.61	0.53	1.14	0.5	1.44	0.75
8	Creative_f	The capstone project reveals it implemented surveillance activities based on multiple methods	-3.02	0.00	0.58	0.95	0.00	0.61	-0.04

Table 4.9 Item Characteristics of the 19 Items of the Final Item Bank in order of difficulty (continued)

						Infit		Outfit	
S/N	Item identity	Item	δi	Measure	SEM	MNSQ	ZSTD	MNSQ	ZSTD
9	Creative_j	The capstone project reveals it implemented health and safety programs	-2.96	0.77	0.66	0.51	-1.39	0.16	-0.56
10	Creative_e	The capstone project reveals it designed surveillance activities based on multiple methods	-2.91	-0.61	0.53	1.65	1.78	1.47	0.78
11	Colab_d	The capstone project reveal it functioned effectively on a team of more than one disciplines	-2.87	0.77	0.66	0.97	0.05	0.49	-0.02
12	Integ_b	The capstone project reveal it is designed to implement new health promotion processes based on multiple methods	-2.74	1.85	0.83	0.59	-0.79	0.12	-0.60
13	Integ_d	The capstone project reveal it formulated new policy(ies) based on multiple methods	-2.74	1.85	0.83	0.59	-0.79	0.12	-0.60
14	Creative_h	The capstone project reveals it implemented a well-designed work process interventions built on more than one disciplinary approach	-2.74	1.85	0.83	0.59	-0.79	0.12	-0.60
15	Creative_i	The capstone project reveals it developed health and safety programs	-2.74	1.85	0.83	0.59	-0.79	0.12	-0.60
16	Colab_b	The capstone project reveals it managed staff/personnel resources used in the project effectively	-2.72	1.25	0.72	1.29	0.77	0.8	0.32

Table 4.9 Item Characteristics of the 19 Items of the Final Item Bank in order of difficulty (continued)

						Infit		Outfit	
S/N	Item identity	Item	δi	Measure	SEM	MNSQ	ZSTD	MNSQ	ZSTD
17	Colab-c	The capstone project reveal it displayed effective leadership over multiple team members and activities	-2.70	1.85	0.83	1.04	0.24	0.22	-0.37
18	Creative_g	The capstone project reveals it implemented a well-designed health promotion and education programs	-2.60	2.74	1.08	0.95	0.20	0.16	-0.49
19	Integ_f	The capstone project reveal it created a new surveillance process in the workplace based on multiple methods	-2.59	2.74	1.08	1.06	0.33	0.22	-0.37

Note: δi = item difficulty estimate; SEM = standard error of measurement

Despite the fit challenges of the serially removed items in Table 4.10 below, the misfit items showed relevance to the construct and maybe could make use of a little modification to achieve model fit. This study envisaged the possibilities and impact such modifications could have on the overall psychometric characteristics of the iCER-OSH, unfortunately, this study did not attempt to do the modification for time constraint and would suggest this in further research.

Table 4.10 Details of items serially (according to misfitting order) deleted.

S/N	Item ID	List of Item deleted serially
1	Colab_g	The capstone reveals it utilized secondary data
2	Creative_k	The capstone project reveals it applied best practices to optimize sustainable activity(ies) plan
3	Colab_f	The capstone project reveals it incorporated data from more than one sources
4	Creative_b	The capstone project reveals it implemented project activities on multiple methods
5	Colab_e	The capstone project reveals it demonstrated attention to thoroughly describing the approach for fulfilling work interaction among peers
6	Integ_g	The capstone project reveals it incorporated data from more than one disciplines

4.2.4 Individual item characteristics

The person-item maps (also called Wright Maps) allow the visual analysis of the relationship between the measures of individuals and items. The use of these maps assists in the assessment of positive and negative issues, such as item redundancy (i.e., items at the same difficulty level), trait gaps (that may indicate the need of more items to fill the gaps), ordering of items matching the prediction of the test author or users (i.e., construct validity), and targeting between the items and sample (i.e., whether item difficulty range matches the sample ability range) (Boone et al., 2014). Figures 4.2 and 4.3 present the distribution of items and persons, items and programs on the logit scale.

The category threshold parameters of the 28 items in the bank spread over a range of 9 logits (-6 to +3) with a wide range of interdisciplinary competencies in OSH (Figure 4.2). The most difficult item in the bank was "The capstone project reveals it designed screening activities based on multiple methods" and "The capstone project reveals it designed surveillance activities based on multiple methods" while there are seven easiest items on the same logit, vis {"The OSH opinion presented in the capstone project is clear to understanding", "The capstone project demonstrates that it writes well to pass its opinion in a concise way", "The capstone project demonstrates that it interprets policies clearly", "The capstone project demonstrates that it disseminates policies clearly", "The capstone project reveals it looked for unexamined linkages in project activities", "The capstone project reveals it looked for unexpected effects in project activities", "The capstone project reveals it offered recommendations for future intervention(s)"}.

The spread of items and their respective location in logit on the wright map in Figure 4.2 reveal a spread over 9 logits (-6 to +3) which seems great for interdisciplinary competencies spectrum. Observable unfortunately from the same map is the redundancy of items and item gaps within the spectrum especially at the -6, -1.62 and 1.84 logits. Also, observable are the marked trait gaps requiring items to fill them. Item characteristics and distribution were found to match theoretical expectation that both integration and creative thinking are challenging to measure, thus most difficult.

Figure 4.2 Wright map (Variable map) of person and items' distribution

```
MEASURE PERSON - MAP - ITEM
        <more>|<rare>
  3           +
              |  Integ_c  Integ_e
              |  Cret_g   Integ_f
              |
              |
              |S
              |
  2           +
            X |  Colab-c  Cret_h   Cret_i   Integ_b  Integ_d
              |
              |
              |
             T|  Colab_b
            X |
  1           +
           XX |
              |  Colab_d  Cret_j
            X |
              |
              |
              |
  0           +M Cret_f
              |
              |
              |
             S|  Comm_a   Comm_f   Cret_e
            X |
              |  Colab_a
 -1           +
           XX |
              |
              |
          XXX |
              |
              |
 -2           +
        XXXXX |  Cret_d
              |S
             M|
              |
              |  Cret_c
      XXXXXXX |
 -3           +
              |
              |
              |
              |
              |
      XXXXXXX |
 -4           +  Cret_a
              |
              |
             S|
              |T
              |
              |
 -5           +
              |
        XXXXX |
              |
              |
              |
              |  Integ_a
 -6           +  Comm_b   Comm_c   Comm_d   Comm_e   Cret_l   Cret_m   Integ_h
        <less>|<freq>
```

Regarding person parameters, Figure 4.3 shows the spread of persons and items. Result shows that 35 persons are spread over 7.18 logits (-5.34 to +1.84) of persons abilities. The capstone with the most abilities is first a capstone in Doctor of Public health in Occupational Epidemiology (+1.84 logit), followed by PhD Occupational & Environmental Health Nursing (+1.08 logit). This was closely followed by all the other 3 Doctor of Public health Occupational Epidemiology. Five capstones demonstrated the lowest of abilities on the instrument at -5.34 logits (2 MPH Agricultural Health & Safety Environmental Health and 3 MPH Occupational Epidemiology). Also, person characteristics and distribution does not match theoretical expectation as the doctoral capstone came a step lower than the Doctor of Public Health capstone with a wide gap.

Figure 4.3 *Wright map (Variable map) of programs and items distribution*

```
MEASURE ITEM - MAP - PROGRAM
      <rare>|<more>
  3        +
      XX  |
      XX  |
          |
          |
         S|
          |
  2        +
    XXXXX  |  DP_OcE_
          |
          |
          |
       X  |T
          |  PH_OcEN
  1        +
          |  DP_OcE_  DP_OcE_
      XX  |
          |  DP_OcE_
          |
          |
          |
  0       X M+
          |
          |
          |
     XXX  |S
          |  MP_AgS_
       X  |
 -1        +
          |  MP_AgS_  MP_AgS_
          |
          |
          |  DP_OcE_  MP_AgS_  MP_OcE_
          |
          |
 -2        +
       X  |  MP_AgS_  MP_AgS_  MP_AgS_  MP_AgS_  MP_AgS_
         S|
          |M
          |
       X  |
          |  MP_AgS_  MP_AgS_  MP_AgS_  MP_AgS_  MS_Mi_1  MS_Mi_2  MS_Mi_3
 -3        +
          |
          |
          |
          |
          |
          |  MP_AgS_  MP_OcE_  MP_OcE_  MP_OcE_  MP_OcE_  MS_Oc_2  MS_Oc_3
 -4       X  +
          |
          |
          |S
         T|
          |
          |
 -5        +
          |
          |  MP_AgS_  MP_AgS_  MS_Oc_1  MS_Oc_4  MS_Oc_5
          |
          |
          |
       X  |
 -6 XXXXXXX  +
      <freq>|<less>
```

4.2.5 Unidimensionality and Local independence

The Rasch model was hinged on these two vital assumptions of unidimensionality and local independence. Unidimensionality indicates that only one single latent dimension (interdisciplinary competencies) is responsible for the common variance in the data, while local independence indicates that during control for the major latent dimension, there shall be no other substantial intercorrelations between the items. Any part of the observations unexplained by the latent Rasch dimensions is called Residuals. In other words, residual is the observed performance of the students on the items minus the expected from the Rasch model. "Unidimensionality may then be assessed by examining the amount of variance explained by the Rasch dimension, whereas evidence for local independence can be found by examining whether the residual correlation matrix holds no additional substantial dimensions" (Forkmann et al., 2009). Linacre (2006) recommended an explained variance of measure greater than 60% by the Rasch dimension, an additional potential dimension is considered good if more than 5% variance explained it. by the greatest potential additional dimension were considered good. In addition, an eigenvalue less or equal to 2 indicated that not more than two items contributed to the potential other dimension, and this presents a strong ground for ignoring such dimension.

The residual correlation matrix was examined to evaluate unidimensionality and local independence using Winsteps 5.3.2. Results are presented in Table 4.11 and show that total raw variance in observation is 44.99 Eigenvalue units while raw explained variance by the persons and items is 25.99

Eigenvalue units which translates to 57.8% of total variance. The raw unexplained variance (Residuals) which is explained by other sources outside of the Rasch model (or other issues which we did not intend to measure) is 19.00 Eigenvalue units which translates to 42.2%. The residuals have metrics spread as unexplained variance in the serial contrasts. The unexplained variance in the first and second contrasts are 6.04 and 2.90 Eigenvalues respectively. The values are greater than 2 Eigenvalues and thus are significant enough to be further investigated as potential dimensions with substantive structures (Linacre, 2006). This indicates that there are items creating a sub-dimension in our data (a common factor other than the Rasch model that clusters the items together) that must be verified. Other contrasts are lower than 2 were thus could be discarded. Of note is that the items loading on the two contrasts are those of integration and creative thinking.

Table 4.11 Standardized Residual variance of the contrasts.

Variance	**Eigenvalue**	**Observed (%)**	**Expected (%)**
Total raw variance in observations	44.99	100.00	100.00
Raw variance explained by measures	25.99	57.80	56.60
Raw variance explained by persons	9.92	22.10	21.60
Raw Variance explained by items	16.07	35.70	35.00
Raw unexplained variance (total)	19.00	42.20	100.00
Unexplained variance in 1st contrast	6.04	13.40	31.80
Unexplained variance in 2nd contrast	2.90	6.40	15.20
Unexplained variance in 3rd contrast	1.92	4.30	10.10
Unexplained variance in 4th contrast	1.50	3.30	7.90
Unexplained variance in 5th contrast	1.33	3.00	7.00

A principal component analysis of linearized Rasch residuals revealed that 6 items are loading on contrast 1 (Table 4.12) while 3 items load on contrast 2 (Table 4.13). This is preliminary evidence suggesting that unidimensionality may not strongly hold since the loadings are high. Keeping these items would be dependent on the relevance of the items and their dimension to the construct.

If items residuals have positive correlations higher than 0.6, then local independence may be jeopardized. Results show that 6 items are in this category and were found to have correlated with an index of 0.6 and above. It was also observed that all the items in the contrasts causing the variance were indicators of integration and creative thinking, inferring that the noise in the instrument is derived from these two competencies.

Table 4.12 PCA analysis of linearized Rasch residuals of Contrast 1

Identity	Item	Contrast	Loading	Measure	Infit MNSQ	Outfit MNSQ
Integ_b	The capstone project reveal it is designed to implement new health promotion processes based on multiple methods	1	0.98	1.85	0.59	0.12
Integ_d	The capstone project reveal it formulated new policy(ies) based on multiple methods	1	0.98	1.85	0.59	0.12
Cret_h	The capstone project reveals it implemented a well-designed work process interventions built on more than one disciplinary approach	1	0.98	1.85	0.59	0.12
Cret_i	The capstone project reveals it developed health and safety programs	1	0.98	1.85	0.59	0.12
Cret_g	The capstone project reveals it implemented a well-designed health promotion and education programs	1	0.63	2.74	0.95	0.16
Cret_j	The capstone project reveals it implemented health and safety programs	1	0.48	0.77	0.51	0.16

Table 4.13 PCA analysis of linearized Rasch residuals of Contrast 2

Identity	Item	Contrast	Loading	Measure	Infit MNSQ	Outfit MNSQ
Cret_d	The capstone project reveals it implemented screening activities based on multiple methods	2	0.79	-2.16	1	2.27
Cret_c	The capstone project reveals it designed screening activities based on multiple methods	2	0.78	-2.17	1.02	3.56
Cret_g	The capstone project reveals it implemented a well-designed health promotion and education programs	2	0.57	2.74	0.95	0.16

4.3 Summary of Findings

This chapter discussed findings and results following extensive review of literature on interdisciplinary competencies and its evaluation in occupational safety and health. A 34 item iCER-OSH rubric was developed from a framework guided by literature and learning objectives of the CARERC program to review the “presence” or “not present” of the interdisciplinary competencies in OSH in the 35 capstone projects of the graduates of the CARERC program and was calibrated using Rasch model. Some competencies that were found to be interdisciplinary in OSH, could be used for evaluating their presence in student work, help teachers focus their attention on what should be concentrated on as they guide and direct students on which competencies to master while they improve on their skills were presented in this study and were matched up to the expectation in literature. Nevertheless, further research will continue to refine these competencies and their definitions due to the dynamic environment of the workplace and the evolving challenges of man, having a framework and calibrated rubric to utilize while improving and evaluating the skills will allow researchers to be constantly updated in the competencies. Adjustments would then be possible for researchers and trainers depending on emerging themes in literature and student responses.

CHAPTER 5. DISCUSSION AND CONCLUSION

Extensive use of rubrics, for both summative and formative purposes at all educational levels worldwide are ubiquitous in literature, equally, empirical support for the benefits using rubric is steadily growing (Panadero & Jonsson, 2020; Brookhart & Chen, 2015; Panadero & Jonsson, 2013; Reddy & Andrade, 2010; Jonsson & Svingby, 2007). “Rubrics are widely utilized in tertiary contexts to assess student performance on written tasks; however, their use for assessment of research projects has received little attention” (Reid et al., 2022). From this bulk of empirical research, we know that the use of rubrics can have significant and positive effects on students’ learning, academic performance, and self-regulation, provided that the design and implementation are adequate. The capstone project design provides an adequate integrated experience and implementation platform to both assess and assist students’ learning experience and performance. This study presents an evaluation process, to clearly confirm the presence or not of interdisciplinary competencies in OSH in the capstones of graduates of the CARERC program. Unfortunately, capstone design experiences continue not only to be the most difficult course to effectively administer due to its resource intensive nature but also challenging to assess (Farr et al., 2013). Moreso, the ones tilted toward written research project (Reid et al., 2022). The challenge above makes this study a difficult one, nonetheless, bold and ambitious attempts were made to achieve the set out aims of the study. The feedback from the assessment of written capstone projects of graduates of the CARERC program allowed for outcomes to be assessed through the development of rubric and the psychometric analysis of student written capstone projects. Rubrics for each process skill can enhance this alignment by creating a shared understanding of process skills between instructors and students. Rubrics can also enable instructors to reflect on their teaching practices with regard to developing their students' process skills and facilitating feedback to students to identify areas for improvement. Students are more likely to develop these crucial skills if there is constructive alignment between an instructor's intended learning outcomes, the tasks that the instructor and students perform, and the assessment tools that the instructor uses.

5.1 The Core Syllabi of the CARERC program

The CARERC program developed an interdisciplinary Syllabus that has core courses with detailed course descriptions that has been broken down to program and Course/Student Learning outcomes to achieve its stated goals. It was observed from the core syllabi that interdisciplinary competencies are not clearly projected throughout appropriately, rather broad themes that could infer or interpreted into relevant indicators were presented in the learning outcomes. The rubric for this study was developed using the expected interdisciplinary competencies as projected by literature and the contents of this syllabus. Capstone reports of program graduates' projects were uploaded to an online repository on the project's website (https://www.uky.edu/erc/trainees/our-graduates). Multiple formats ranging from varying number of chapters to chapter titles were immediately observed and this attests to the interdisciplinary nature of the program and its possible challenging evaluability potential. This repository is not peer reviewed, but studies received institutional review board approval. Authors upload completed written Capstone Projects thesis/dissertation to the website after approval of satisfactory work from their advisory committee, and these are publicly accessible on the program's website. The core syllabi document in the appendix of this document serves as evidence of teaching curriculum for the program. A review of the contents and learning outcomes in this document shows great learning outcomes but not very clear in the requirements for interdisciplinary competencies. Currently, thirty-five (35) approved reports are uploaded on the site. This study developed a dichotomous scaled rubric to confirm the “presence” or “not” of the constituent items that demonstrate interdisciplinary competencies in a written capstone project.

5.2 Discussion

“The necessity of interdisciplinary science as a critical factor in solving real-world problems is undeniable. Yet, little has been done to assess whether future scientists are equipped with the resources to address this competency” (Tripp et al, 2020). This study is an effort to address the above via identifying relevant interdisciplinary competencies from literature, to develop a framework to initiate a calibrated dichotomous rubric fit to confirm the presence or not of interdisciplinary competencies in occupational health and safety specifically in the capstones of CARERC program graduates.

By restating the initial questions that informed this study, it becomes easy to interrogate the results and establish from literature what the content of the viable rubric for interdisciplinary competencies in OSH would be.

5.2.1 Research Question One

How does the literature compliment the expected interdisciplinary competences in Occupational Safety and Health of graduates on the CARERC program?

This section of the study focused more on the development portion of the rubric. The process relied on existing research on interdisciplinarity and competencies in occupational safety and health which ultimately informed the relevant skills expected or required of graduates of the program.

Results of literature review in interdisciplinarity; interdisciplinary understanding, thinking, science, education; interdisciplinary habit of mind; cross-cutting competencies in occupational safety and health (Olson et al., 2005; Boix Mansilla & Duraising, 2007; Repko, 2008; Boix Mansilla et al., 2009; Borrego et al., 2009; Daud et al., 2010; Crisp & Muir, 2012; Lattuca et al., 2012; Newton et al., 2012; Svobodea et al., 2013; Olcese et al., 2014; Repko & Szostak, 2016; Drake & Ruid, 2017; You et al., 2018; Newell & Luckie, 2019; Tripp & Shortlidge, 2019; Ciraldo, 2020; Claus & Wiese, 2019; ACOEM, 2020; Tripp & Shortlidge, 2020; Tripp et al., 2020) in addition to the core syllabi of the CARERC program were employed to aggregate the main interdisciplinary competencies around the ten competencies listed in Table 10 as: Disciplinary grounding, a demonstration of grounded understanding of their primary discipline (Boix Mansilla & Duraising, 2007; Boix Mansilla et al., 2009; Borrego et al., 2009; Tripp & Shortlidge, 2019; Tripp & Shortlidge, 2020); Recognition of determinants and enablers of OSH challenges (Olson et al., 2005; ACOEM, 2020); Control and prevention of OSH issues and problems (Olson et al., 2005; ACOEM, 2020); Disciplinary humility which recognize and accepts its own limitation to adequately proffer total solution (Peterson et al., 2010, Byrne & Mullally, 2016; Mullally & Byrne, 2016; Tripp & Shortlidge, 2019; Dammann, 2020; Byrne et al., 2023); Understand the ethical and legal regulations around OSH issues and problems (Olson et al., 2005; ACOEM, 2020); Evaluate the impact of OSH issues and problems (Olson et al., 2005; Lattuca et al., 2012; ACOEM, 2020); Communication (Olson et al, 2005; Stein, 2007; Claus & Weise, 2019; Blom et al., 2021; Ciraldo, 2020; Ocloo et al., 2021); Collaboration (Bronstein, 2003; Stein, 2007; Fewster-Thuente et al., 2008; Petri, 2010, Claus & Weise, 2019; Newell & Luckie, 2019; Tripp & Shortlidge, 2019); Integration (Repko, 2008; Mentkowski & Sharkey, 2011; Repko & Szostak, 2016; Tripp & Shortlidge, 2019; Tripp & Shortlidge, 2020; Davidesco & Tanner, 2020) and Creative thinking to apply holistic well-thought out and consulted plan to OSH issues (Tripp & Shortlidge, 2019; Tripp & Shortlidge, 2020; Blom et al., 2021).

Overall, 10 competencies and 81 indicators were concluded to be relevant and necessary to adequately evaluate interdisciplinary competencies in occupational safety and health. These were further utilized to develop both the iCER-OSH framework and instrument. The process and the competencies emerging from this study offers Educational Research Centres (ERC) and other programs involved in training and capacity developments of professionals, platforms to not only evaluate their programs but also present transparent expectations of learning outcomes for program effectiveness. Therefore, the calibrated indicators and their respective competencies also could be exploited for development of intending learning outcomes of courses meant to train in competency proficiency. The above would agree with Ali's (2018) allusion that ensuring that assessment, teaching, learning and feedback should be in synchronous with each other, and that feedback links well to students' evidence of demonstrating their achievement of the intended learning outcomes".

The capstone project culminates the learnings and experience of the graduates of the program and thus, should have served as the window to the proficiencies the CARERC program stands to develop in students, mainly the interdisciplinary competencies in OSH. Unfortunately, this study reveals that the capstones did not significantly demonstrate these competencies. Despite that the capstones delve into interdisciplinary problems; most were focused on adequate framing of the problems, strong evaluation methods and recommendations of viable solutions. Few or none proceeded to implement the solutions or show how they employed the interdisciplinary competencies to bring the solutions. It thus appears that most of the indicators of interdisciplinary competencies will be visible in the capstones as they report implementation activities and stages. The absence observed of the indicators of interdisciplinary competencies in OSH in the capstones therefore misrepresented the investments of the program and failed to prove that the students developed or learned the competencies. Meanwhile, the capstone is the major visible output of the program online.

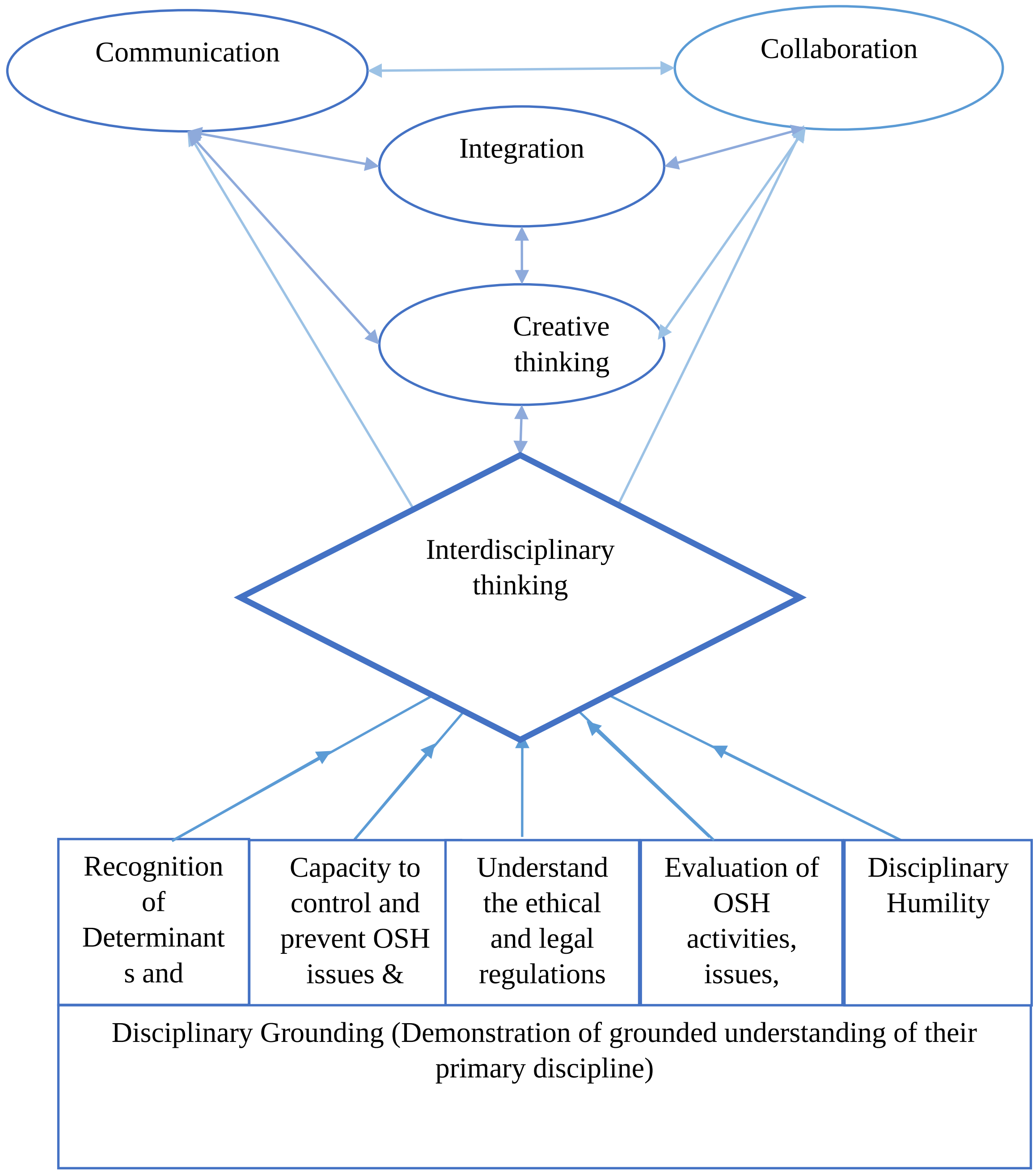
5.2.1.1 Outcome using the iCER-OSH Framework and instrument.

The iCER-OSH framework (Figure 5.1, pg. 203) is a major outcome of this study as it builds upon the foundations of literature to present a template for interdisciplinary competencies, where the possible orientation of the competencies and their hypothetical interactions was towards an interdisciplinary expression. This study hypothesizes that disciplinary grounding, a major competency agreed upon by almost all literature, serves as the bedrock (as shown in figure 5.1, pg. 203) from which all interdisciplinary efforts start. In other words, it is the platform on which all other interdisciplinary activities commenced, and this is in consonant with (Boix Mansilla & Duraising, 2007; Boix Mansilla et al., 2009; Borrego et al., 2009; Tripp & Shortlidge, 2019). Building on the bedrock of disciplinary grounding is a set of core competencies that inform the direction of expression of the interdisciplinary competencies. In order words, the contributory complimentary competencies at this level informed the interdisciplinary thinking which is hypothesized to be the intermediate between input competencies and output competencies. The above is supported by the iceberg model of competencies (Spencer & Spencer, 1993), which views competency as comprising visible (top of the iceberg) and invisible (submerged part of the iceberg). It further postulated that the invisible (input) complimentarily contributes to the visible. This framework is therefore extending that the five competencies (at this level as presented in figure 1 complimentarily contribute to the interdisciplinary thinking and ultimately inform the expression of the four competencies (integration, collaboration, creative thinking and communication). By the same extension, it postulates that the kind of expression of interdisciplinarity would be informed by the complimentary components. Based on the outcome of the reviews and prevailing definitions of interdisciplinary research as advanced by the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine as presented below that Interdisciplinary research (IDR) is a mode of research by teams or individuals that:

> "Integrates information, data, techniques, tools, perspectives, concepts, and/or theories from two or more disciplines or bodies of specialized knowledge to advance fundamental understanding or to solve problems whose solutions are beyond the scope of a single discipline or area of research practice (National Academy, 2005, p. 39)"

This study based on the above common definition and in agreement with integrationists further advances as shown in Figure 5.1 below that the concept of integration is central to the entire interdisciplinarity discuss and can be seen threading through the entire competencies and informs how you communicate, collaborate of think creatively to arrive at the cognitive advancement which is the end goal of any interdisciplinary endeavor. It thus put the competence of integration as the central influencing competency for all other competencies and that may offer some explanation to the multidimensionality displayed by the iCER-OSH especially around the integration and creative thinking competencies.

Figure 5.1 *Modified iCER-OSH Framework*



Interdisciplinary Thinking

An emerging outcome of the framework was interdisciplinary thinking which forms the intermediate between the visible and invisible sets of competencies. This intermediate is viewed as a potpourri of competencies that informs a mindset or disposition to reflect on approaching task from a perspective that holistically looks at multiple ways and methodology to resolve the attending issues. It is hypothesized in this study that contributory disciplinary perspectives could determine or inform the types of creativity and cognitive advancements that will be observed as outcome of the interdisciplinary venture, and this statement is suggested for further studies. This stage of interdisciplinarity could also differentiate the specificity of core competencies that differentiate emerging fields. The notion of interdisciplinarity as a continuum (Lattuca, 2001) could also be easily explained at this level where outcomes or cognitive advancement is reflected at different levels of the relationship between the different components that informed the thinking. Prior to this study, interdisciplinary thinking as presented by authors especially Tripp and Shortlidge (2020) who in their Interdisciplinary Science Framework (IDSF) presented it as the medium in which the science of interdisciplinarity takes place and must be intentionally infused into curricular and pedagogy. This study agrees with the above and pushes a little further thus hypothesize that specific competencies suite will complimentarily facilitate this state of thinking.

Also, important and emerging from both literature and the iCER-OSH framework is the complementarity properties of the competencies emerging from interdisciplinary thinking which argues that the competencies are not interdisciplinary in isolation as each contribute to a whole that exists as a continuum.

5.2.1.2 Components of the Rubric to measure interdisciplinary competencies in Occupational Safety and Health

Competencies should not only be defined and practiced through appropriate assignments during a course or curriculum, but they should also be assessed effectively (Blom et al., 2021). In assessing these competencies, indicators must fairly reflect and capture the components of constructs, such that learners could pick them and work from them to develop and culminate proficiency in the relevant competencies. In the same vein, teachers could pick the indicators and tease out learning outcomes that facilitate effective teaching and transfer of the competencies. This study has successfully defined and compiled a list of competencies that successfully capture interdisciplinary OSH proficiency that could benefit students of ERC and other training programs. Consequent upon the above the relevant competencies are discussed below:

5.2.1.2.1 INTEGRATION

Most literature presents integration as the most challenging to measure of all the interdisciplinary competencies (Repko, 2008; Mentkowski & Sharkey, 2011; Repko & Szostak, 2016; Tripp & Shortlidge, 2019; Tripp & Shortlidge, 2020; Davidesco & Tanner, 2020). Integration in written work becomes more challenging and is in consonant with the findings of Tripp and Shortlidge (2020) who observed discrepancies between the interviews and essay scores, as more than half of the students showed integration knowledge and critical awareness constructs in their interviews but not in their essays. Initial findings from the review of literature shows integration as the major outcome of interdisciplinary competencies and this competency is seen threading through all other competencies. Figure 5.1 shows how this competency interrelates with other competencies. The authors concluded from the findings above that the rubric did not fully capture students' interdisciplinary understanding and proposed that a framework might be more suitable for interdisciplinary assessment. The major challenge to assessing integration has been cognitive advancement that would have been impossible without the contribution of more than one discipline and the varieties of things it could interpret to. Notwithstanding, various laudable efforts had been made to ensure adequate capture of the indicators of this competency. Result from this study is not different as it was observed that most indicators of integration were absent from students' capstone. Further, this study has ambitiously in consonance with literature and peculiar to its sample has considered indicators like creation, design, formulation and implementation based on multiple methods of programs, guidelines and policies. The ambition was further extended to include incorporation of data from multiple sources and offering feasible recommendations for future interventions. The results appear to tilt the focus on the issues that arise in the analysis of data from the presence of interdisciplinary competencies which are quite different from those found in more traditional work settings. Thus, the ambitious introduction into the indicators was the major evidence of integration in the capstone, which may invite an extension of the definition of integration to include such indicators particularly when considering specific written work.

It was also observed that none or few of the capstone projects has reported on providing programmed solutions or interventions to the OSH problems (All have ended in recommendations). This absence observed could be explained by the time frame limitation compelled by the short duration of the programs. Notwithstanding, almost all proposed feasible recommendations and suggestions for future interventions. Also, despite the poor demonstration of indicators of integration in most of the reviewed capstones, i.e. {the capstone project reveals it is designed to implement new health promotion processes based on multiple methods (5.7%), the capstone project reveals it formulated new guideline(s) based on multiple methods (0%), the capstone project reveals it formulated new policy(ies) based on multiple methods (5.7%), the capstone project reveals it created a new culture of wellness in the workplace based on multiple methods (0%), the capstone project reveals it created a new surveillance process in the workplace based on multiple methods (2.9%)}, the strength of most of the capstones lies in the use of data from multiple and sometimes unrelated sources (like using agricultural or geological and population data to make inferences in health) to draw conclusions. This, in the perspective of the researcher in this study fulfilled some of the requirements of cognitive advancement to a great extent. In addition, the use of secondary data is assumed in this study to be strong evidence of identified gaps in specific personnel, especially when the data are from obvious different field of study i.e., like using agricultural or geological data to make inferences in health.

It may therefore be suggested from the foregoing that the definition of integration may need to be expanded to include methodological/data integration, incorporation or jumbling irrespective of whether it was termed or continued to cognitive advancement. This study argues that the three performing indicators were more relevant and realistic to written work prepared by students with both limited resources in time especially and possibly materials.

Also, the notion of multiple viable possible integrations as proposed by Tripp & Shortlidge, (2020) could explain the observed lack in the demonstration of the competency and may be because they are other possible integration indicators that the iCER-OSH instrument was unable to capture.

5.2.1.2.2 COLLABORATION

Hesitancy to collaborate even between experts of different disciplines in even purported interdisciplinary environment is not strange (Claus & Weise, 2019; Tripp & Shortlidge, 2020; McCullagh et al., 2022). It was also observed that deliberate efforts to ensure experts from different fields working together is a common theme in literature as it appears this skill does not come naturally (Tripp & Shortlidge, 2020; McCullagh et al., 2022). Also, studies have shown that a written report is usually insufficient as it usually does not provide insight into the functioning of individuals in a team. It is thus recommended that samples or collection of work from other sources like student’s own reflection, evaluation feedback from fellow team members and an outside observer's evaluation regarding the student's contribution to a team's dynamics would be complimentary (Tripp & Shortlidge, 2020). It is not strange then to see results from this study show that there are few or no demonstrations or reflection of collaborations between and among the students of the CARERC project. The explanation for this absence would be first the human problem that find it easy to work in silo even when he is expected to work with others and specifically in this study could be the shortness of the duration of their study, their project goals which were mostly focused on identifying problems, checking their prevalence/status of the problems, or analyzing the problems. Also, the expectation of independence in study and research plus the personal expectation in assessment of competency which characterize higher education may also explain the solitary presentations of capstones by the students. Notwithstanding, this study ambitiously introduced indicators that confirmed if data was incorporated from more than one source or if the capstone project utilized secondary data. This ambition is based on the belief that the data, especially those that used data from non-related fields like Agriculture and Medicine is already collaborating in a way. Also, a number of studies explored multi methods involving data from varied fields, despite not evidently involving personnel from more than one discipline. There were cases of drawing health conclusions from agricultural and ecological data. In addition, titles and contents reveal interdisciplinary directions and pursuits despite that projects may not exclusively reflect participation of more than one disciplinary personnels. Most contents and methodology were also sound and interdisciplinary despite the observed absence of personnel collaboration. This is argued as identification of disciplinary or personnel gap as decisions were made with the contribution of others and different discipline.

5.2.1.2.3 Creative thinking

Creative thinking was one of the skills needed for the future (Drake & Reid, 2020), Chen and Wang, (2021) identified it as 21st century skill, Klein (2002) termed it as one skill that is not assessable and "often viewed as intangible that can be viewed in impact and consequences" (Foster et al., 2022). Despite the above, creative thinking or creativity as some literature inferred has facilitated advancement in varying areas of human endeavor. Foster et al (2022) has argued that "it should be defined as a tangible competence, grounded in knowledge and practice, that supports individuals in achieving better outcomes, often in constrained and challenging environments". This study is joining the discourse with efforts at presenting viable indicators of measuring creative thinking. Being an offshoot of interdisciplinary thinking as hypothesized in the iCER-OSH framework (Figure 1) suggests that there are complimentary and contributory competencies. The notions of designing and implementing project activities based on multiple methods and proceeding with specific activities peculiar to OSH (screening, surveillance, health promotion and education, health and safety programs) that would have demonstrated creativity. Also, this study ambitiously introduced "looked for either "unexamined" or "unexpected" linkages/effects in project activities are genuine effort at evaluating the presence of creative thinking.

In the overall, most capstone project (71.4% and 88.6%) demonstrated that they designed and implemented project activities on multiple and possibly unrelated methods respectively (like incorporating GPS data, labor statistics and agricultural outcomes, Geological survey and birth defects registry, the Census of Agriculture, and the American Community Survey databases) to track prevalence and cause of disease. Also, most capstone projects struggled or failed to come up with well-designed or implemented {screening (51.40 & 42.90%), surveillance (22.90 &17.10%), health promotion and education (2.90 & 5.70%), health and safety programs (5.70 & 11.70%), yet they all sought unexamined and unexpected linkages/effects as they weave seemly unrelated data to arrive at the conclusion of their projects. The failure observed may also be related to generalization of expectation in literature of what the outcomes of a capstone should be. This study argues that the four performing indicators were more relevant and realistic to written work prepared by students with both limited resources in time especially and possibly materials.

In addition to the above, only about 22.90% of capstone projects demonstrated that it applied best practices to optimize sustainable activity(ies) plan. This was in the form of deliberate data protection plan and training county health officials in ways to continue implementing their findings. Others may also have implemented this, but it was not reflected in their capstones. This may imply that the capstones like other research documents may just sit on the shelf with limited utility, should no other efforts be made to disseminate and train others on its utility.

5.2.1.2.4 COMMUNICATION

Communication was always perceived as soft skill; it is considered as one of the crucial skills to interdisciplinary collaboration (Chen & Wang, 2021). It could be verbal or non-verbal, oral, or written. “It includes being open minded and non-judgmental in listening to and trying to understand other’s perspectives” (Blom et al., 2021). Clear explanation becomes vital since team members with unrelated disciplines usually do not share the same background. So also, should be aware of the diversity of disciplinary language, understandings, and terminologies. Most capstone projects in this study do not demonstrate any difficulty in explaining concepts and project activities (100% in indicators of presentation, writing clearly, interpretation and dissemination of policies). However, 77.10% of capstones neither demonstrate communication with other experts or stakeholders nor discuss effectively with other safety and health professionals respectively. The observed poor communication may be explained by any of the other reasons already discussed regarding other competencies.

5.2.2 Research Question Two

What are the psychometric properties of the developed interdisciplinary competence assessment Rubric?

The calibration of iCER-OSH rubric is one of the major objectives of this study. To further the above, the equivalence of item functioning of the iCER-OSH was examined in the written capstone projects of the graduates of the CARERC program. A calibrated item bank is a necessary precursor for evaluating interdisciplinary competencies and may be presented as basis for development of specific diagnostic instrument for relevant programs. Analysis resulted in 19 items that fit the Rasch model, demonstrated good psychometric properties and measured “competencies” unidimensionality and across a broad spectrum of interdisciplinarity. Also, there were 9 items that were constantly with minimum and maximum measures and may still find relevance in the overall rubric. Most items retained in the bank contain a fair share of the four interdisciplinary competencies focused upon in this section of the study, while some items did not fit the model contrary to the expectation. Notwithstanding, the current item bank of 19 items presented in this study may be of great use in confirming the presence or absence of interdisciplinary competencies in written submissions from students. The fit statistics are also by implication evidence of some measure of the validity of the data model fit, as a diagnosis of individual peculiarity, and ultimately of the items and the overall iCER-OSH rubric. The calibrated items also hold great potential for the evaluation of specific competencies within and outside of interdisciplinarity and especially in other ERCs and training programs by extension.

Item separation and persons separation also revealed that the rubric is reliable enough to measure interdisciplinary competencies in OSH and it differentiates between approximately 2 strata of persons ability and about four strata of items difficulty. This is considered good and clearly exceeded critical values. This outcome offers great credence to the ability of the iCER-OSH to not only evaluate interdisciplinary competencies, but also to discriminate between students' ability to demonstrate the competencies in their capstone project write up. The level of abilities observed could also to some extent infer how proficient a graduate of the program would be when confronted with relevant tasks.

Examination of dimensionality demonstrated potential secondary dimensions constituted by 6 items loading on contrast 1 (Table 21) while 3 items load on contrast 2 (Table 22). However, the details of the items loading, and their implications are beyond the scope of this study. Equally, local independence may be jeopardized in these items due to the same 6 items since they correlated with index beyond 0.6 minimal expected in literature. The first implication of the result above is the possibilities of other dimensions that require further investigation. This serves as preliminary evidence suggesting that unidimensionality may not hold for the iCER-OSH rubric and would result in biased parameter estimation of the test. Ideally, there should be no significant correlations among the items after the contribution of the latent trait is removed, i.e., among the residuals. Contrary to expectation, the outcome of the iCER-OSH is different and shows that the items are locally dependent or there is a subsidiary dimension in the measurement which is not accounted for by the main Rasch dimension (Lee, 2004). The above may also be interpretable in line with the fact that interdisciplinarity itself is a continuum with multiple complimentary dimensions. Moreso, it was also observed that there was a lot of duplication and repetition of themes. A lot was put into pruning the indicators to ensure that there were few or no redundance of items. The strong correlation observed in the dimensions could also indicate areas of complementarity between the competencies as they have been observed not to be strictly exclusive. Keeping these items would then be dependent on the relevance of the items and their dimension to the construct.

5.2.2.1 Individual item characteristics

Regarding item spread and location on the logit as shown on the wright map in Figure 2 There appear to be 6 clusters of items on the entire range. Each cluster is on the same logit and could indicate a level of redundancy where the items appear to be assessing the same indicator. On closer look, the cluster on logit -6 loads 7 items {"The OSH opinion presented in the capstone project is clear to understanding", "The capstone project demonstrates that it writes well to pass its opinion in a concise way", "The capstone project demonstrates that it interprets policies clearly", "The capstone project demonstrates that it disseminates policies clearly", "The capstone project reveals it looked for unexamined linkages in project activities", "The capstone project reveals it looked for unexpected effects in project activities", "The capstone project reveals it offered recommendations for future intervention(s)"}, these items clearly measure different indicators of specific competencies despite location on the same logit; thus, instead of redundance here, the same level of difficulty is indicated would be preferred. The cluster on logit -1.4 loads 3 items {"The capstone project demonstrates that it communicates effectively with a variety of stakeholders (e.g., management, labor)", "The capstone project demonstrates that it discusses effectively with other safety and health professionals" and "The capstone project reveals it designed surveillance activities based on multiple methods"}, while the first two items here might indicate a lot of redundancy and could be merged into one, the third item clearly reveal a different indicator of another competency despite location on the same logit which indicates same level of difficulty rather than redundance in this case. A cluster of 2 items exist on logit +0.7 ("The capstone project reveals it functioned effectively on a team of more than one discipline" and "The capstone project reveals it implemented health and safety programs"); the two items may be on the same logit, but clearly measure 2 different indicators and could not be termed redundant but are same in difficulty levels. There is a cluster of 5 items on logit +1.94 {" The capstone project reveals it displayed effective leadership over multiple team members/activities", "The capstone project reveals it implemented a well-designed work process interventions built on more than one disciplinary approach", "The capstone project reveals it developed health and safety programs", "The capstone project reveals it is designed to implement new health promotion processes based on multiple methods" and "The capstone project reveals it formulated new policy(ies) based on multiple methods"}; the same can be concluded for the items above as they are only on the same level of difficulty and not an indication of redundancy. There is a cluster of 2 items each on logits +2.86 {"The capstone project reveals it implemented a well-designed health promotion and education programs" and "The capstone project reveals it created a new surveillance process in the workplace based on multiple methods"} and +2.94 {"The capstone project reveals it formulated new guideline(s) based on multiple methods" and "The capstone project reveals it created a new culture of wellness in the workplace based on multiple methods"} respectively; despite being located on the same logit, the items are indicators measuring parameters peculiar to specific competency and only have the same difficulty level but could not be termed redundant.

The Wright map (Figure 2) also reveals item gaps that could still be filled with relevant items and indicates field gaps that require further research.

The wright map in Figure 3 also shows the person's spread and location on the logit. It was observed that the persons that demonstrated the presence of most of the interdisciplinary competencies using the iCER-OSH rubric is a capstone in Doctor of Public health Occupational (DPH) Epidemiology (+1.84 logit), followed by Doctor of philosophy capstone (PhD) Occupational & Environmental Health Nursing (+1.08 logit). This was closely followed by all the other 3 Doctor of Public health Occupational Epidemiology. Five capstones demonstrated the lowest expression of the interdisciplinary competencies using the iCER-OSH rubric at -5.34 logits (2 MPH Agricultural Health & Safety Environmental Health and 3 MPH Occupational Epidemiology). This performance of the PhD and DHP capstones may reflect the extent of expectations at this level of education and is in consonant with literature and educational expectation of proficiency. It would only have expected that the PhD should have presented the most competencies. It should also be noted that the level of proficiencies demonstrated in this study does not interpret to poor or shoddy project outputs demanding a failure grade. Rather, literature revealed that this kind of output is prevalent in written reports. It is thus recommended that samples or collection of work from other sources like student's own reflection, evaluation feedback from fellow team members and an outside observer's evaluation regarding the student's contribution to a team's dynamics and revealing other interdisciplinary competencies would be complimentary to confirm proficiency (Tripp & Shortlidge, 2020).

5.3 Conclusion

As this dissertation has shown, this rubric successfully evaluates the presence or not of the interdisciplinary competencies in occupational health and safety and its calibration supports the claim that CARERC and other programs could find utility and relevance in using this rubric. Considering that interdisciplinary education is becoming more desirable and popular for obvious reasons, this rubric is projected to serve the purpose of helping to confirm that students are being trained in the relevant competencies.

Overall, the performance of the capstones using the iCER-OSH instrument has shown a poor demonstration in interdisciplinary competencies in OSH, especially Integration (3 out of 8 indicators show above 50% of the indicators present), collaboration (2 out of 7 indicators present above 50%) and creative thinking (5 out of 13 indicators present above 50%). The result seems to not only reinforce conclusions from literature that integration and creative thinking competencies are challenging to measure, but also that they are equally challenging to demonstrate in written work. In the same vein, the hesitation to collaborate or failure to actually demonstrate interdisciplinary competency in collaboration observed could also be that it may not be easy to demonstrate it in so called independent work. This study shows that the observed absence of some criteria and indicators in the capstone projects may not be due to incompetence in the skills but could be due to the expectation of independence and originality in academic program outputs, that seldom prevents people from jointly presenting reports for grade and credentials. Student and teachers may split obvious joint work between students to fulfil the clause “that my thesis or dissertation and abstract are my original work”. Although, this challenge is systemic and must be addressed in such a way at the institutional level, and in the light of the peculiarity and goal of programs especially interdisciplinary based ones.

From the foregoing, it therefore suggests that interdisciplinary programs especially must make deliberate and considerable effort to teach and encourage learners to be both proficient in demonstrating these competencies on the job and in written work opportunities and how to specially communicate their proficiency in their written work opportunities, especially that this may be the only avenue for non-team members and community of practice to both see their novel outputs and learn from them. Rubrics of this nature especially iCER-OSH that demonstrate evidence of indicators of assessment would be useful in guiding learners and teachers of interdisciplinary programs and other ERCs on specific transparent expectations in both learning outcomes and outputs.

Capstone objectives were observed to affect the kind of criteria and indicators that would be observed in the overall. Unfortunately, most of the capstones focused on identifying problems, or the prevalence or state of the problems, or analyzing the problems. None or few has reported on providing programmed solutions or interventions to the OSH problems (All have ended in recommendations). These omissions may in addition be easily explained by the duration of stay on the program or that interventions were not reported in the capstones. The iCER-OSH rubric offers wide applicability for learners of interdisciplinary and other trainings programs on specific competency expectations right from the conception and design stage of their capstones. The paradigm shift here would be that learners and teachers equipped with such transparency expectations like the iCER-OSH rubric offers would be conscious of competency expectations as they conceptualize and design their capstones and would also have made provisions for reporting and assessment from the onset.

Also, most programs culminating in capstone incorporate other learning activities like field experience or seminar presentations which demand clear expectations of working with other experts in teams. Such activities are also assessed with cognizance of collaboration and are contributory to final grading. They sometimes are more focused on assessing the demonstration and evidence of the interdisciplinary competencies in such activities.

Details of psychometric properties, especially at item and person levels are omitted in this study as they are beyond the scope of this study. As it were, the iCER-OSH rubric in its current form following the serial deletion (19 items) consist of indicators of all the four competencies of concern i.e., Integration (4); Communication (2); Collaboration (4) and Creative thinking (9), albeit in varying scope, appear to be fit for use as it would readily capture the presence of interdisciplinary competencies in OSH. However, the challenge of trait gaps and the presence of other dimensions as evidenced by the residuals of contrast 1 (6 loaded items) and contrast 2 (3 loaded items) may undermine this fitness for use. Since this indicates that the iCER-OSH instrument surely has additional dimensions other than interdisciplinary competencies in OSH, and these other dimensions must be ascertained, and the gap be confirmed not to be unconstructive to the measurement before it can be recommended for use. This suggests the need for further research in this area.

It was also observed that all the items in the contrasts causing the variance were indicators of integration and creative thinking, inferring that the noise in the instrument is derived from these two competencies. It would be desirable to know what dimension(s) they contribute to the interdisciplinary competencies in OSH and how this will affect the overall performance of the iCER-OSH. A multidimensional Rasch model is suggested to unravel the latent traits causing the variance in the iCER-OSH rubric and especially in the two competencies. The iCER-OSH rubric was designed to evaluate the “presence” or “not” of interdisciplinary competencies in OSH; it will do this well considering the items constituting it and their distribution across the competencies of concern as earlier stated. The iCER-OSH also holds the capacity in its current form to confirm the “presence” or “not” of the relevant competencies when applied to capstone projects or other written student outputs of students of other ERCs too.

In order to improve the utility and the measurement precision of the iCER-OSH, it would be great to resolve the issues around the dimensionality as earlier stated to ascertain and ensure its unidimensionality. Meanwhile, this could serve as an item bank fit to measure the presence across the continuum of interdisciplinary competencies ranging from capstone focus like implementing intervention/process, formulation of new guidelines/policy to creating a new work culture/ surveillance process. Tripp s& Shortlidge (2020) reported the development of both the Interdisciplinary Science Rubric (IDSR) and Framework (IDSF) as the closest ever to assess or evaluate interdisciplinary thinking in undergraduate students' essay. However, the item banks were not developed to target the presence or not of interdisciplinary competencies. Furthermore, the item bank developed in this study holds a couple of potential advantages as it is more in number, covers a broader spectrum and focused on clear interdisciplinary indicators of the competencies rather than on foundational competencies. Also, the number of items in the iCER-OSH provides an advantage for repeated assessment as the probability that items will be presented twice to a capstone in a repeated measurement declines significantly. Additional effort could be made to make the rubric more concise and categorize the degree of presence of the competencies between "strong", "moderate" and "weak". While working towards a more concise rubric, the choice of item from the iCER-OSH rubric bank would depend on the end goal of the capstones as presented such as implementing intervention/solution, formulation of new guidelines/policy or creating a new work culture/surveillance process. Notwithstanding the above, the iCER-OSH rubric can and should not be taken as a one-size fit all rubric for evaluating interdisciplinary competencies.

Following the above, the utility and measurement precision should increase and would help both teachers and students on the CARERC program to easily itemize interdisciplinary competence indicators relevant to each learning outcome of the core syllabi. With clear itemization of the indicators, it becomes easy to set clear goals and expectation of capstone projects and what should go into the different section of the report. The item bank can further be used as the basis for development of fixed-length rubric and researchers may compose sets of items for their specific assessment needs.

5.4 Recommendations

The first recommendation of this study is the iCER-OSH framework which offers commendable explanation and foundation to the relationship between components of interdisciplinary competencies. The field of interdisciplinary competencies has battled the notions of core and specific competencies, but few studies have shown how the components interrelate to complement interdisciplinary outputs. This study has attempted to reveal this hypothetic complementary interaction that culminate in interdisciplinary thinking and how what core components that informed the thinking would determine the specific competency output that would be demonstrated and visible on the task.

In addition, considering that the capstone project is the only output or product of the CARERC program that is virtually accessible to the public. It becomes a great disservice if the capstones are unable to completely project the ideals and goals of the program despite the input of the teachers and the students with the robust curriculum. Unfortunately, this is the situation as the capstones are lacking in demonstration of some of the expected interdisciplinary competencies which are the core objectives of the program. It is thus recommended that the CARERC must find a way of ensuring students adequately articulate the interdisciplinary competencies in this visible output which serves as the only town-gown platform to confirm that the program is achieving its set out objectives and that graduates are truly developed in these expected competencies.

Though challenging, capstone projects offer rewarding experience to students since the extensive knowledge acquired during the process boosts students' professional skill and offers opportunities for hands-on experience which is a key advantage. While recognizing that capstone projects are usually supplements to the usual final examination and allow students a practical application of their learning. Another option may be to find alternate ways to project other activities like field reports, supervisors report etc. that clearly demonstrate these expected competencies on the public virtual space. Since most indicators of interdisciplinary competencies in OSH are obvious during reporting of implementation stages or field activities, it would be great if the reports of such activities were included in future capstones of the program. Equally, elements of collaboration in a capstone project should not be expunged in order for the work to appear individual, rather such activities should be projected as evidence of interdisciplinarity. It is highly recommended also that capstones could strengthened to reveal interdisciplinary competencies if teams are assigned to a problem with different person leading separate sections and thus reported for every team member and their sectional contributions. As earlier suggested also, demonstrating competencies like collaboration and integrations in the capstones may have been challenging for learners due to degree requirements of independence and originality. Notwithstanding, the challenge of demonstrating the competencies, concerted efforts at ensuring incorporation of training components to equip students to present learned competencies in written work is highly recommended for the ERC programs and other competency-based trainings.

In view of the requirements of independence and originality of thesis/dissertation including capstones by degree granting institutions. This study argues that originality and independence of research work does not in any way negate nor undermine collaboration and interdisciplinarity rather, they should be complementary. This work thus suggests that the requirements for independence and originality could be catered for at the point of integration such that how and what each learner contributes to the work to arrive at integrated output or cognitive improvement could be specified even in joint work. Assessment of joint work must then incorporate indicators of integration to judge independence and originality at that level. The iCER-OSH rubric offers so much promise and is recommended for interdisciplinary programs to resolve the above (Reid et al., 2022). For most of the capstone reports submitted and present on the virtual repository, only what is captured can be evaluated which may impact on how the outcome is perceived.

To strengthen this rubric, it is highly recommended to have multiple independent raters (at least 3 others) use the rubric to review the submitted capstones in order to have multiple perspectives and also improved reliability and validity reports on the rubric. Coupled with the above would have been the rich perspectives of the students and teachers on the program about the competencies that they consider core and vital to interdisciplinary competencies in OSH. Information like above is recommended to reinforce the validity of the expected competencies. A multidimensional Rasch model, factor analysis or structural equation modelling of the hypothetical iCER-OSH framework would also have contributed immensely to the relationship and orientation of the components that made up the framework, adequately understand the residuals contributing to the behavior of the rubric and would provide robust foundation for the discourse on competencies and interdisciplinarity. In addition to the above, Test Information Function (TIF) of the item bank is highly recommended since "test information assesses the informative value of an entire test", a test estimates examinee's ability, since every ability level comes with concomitant extent of information is also suggested in future research using this rubric. This may provide more information on the quality of the entire rubric.

Furthering this, other studies may investigate how the foundational OSH competencies elucidated in the iCER-OSH framework could be evaluated. Also, the evaluation of the course curriculum is suggested as a further study in order to streamline the disparities between the submission format and comparative review with the core syllabi of the program.

5.5 Implications for Evaluation

This study could have several implications for future research in rubric development and evaluation, especially in interdisciplinary studies and other training programs. This study, among other issues, attempted and resolved the challenge of assessing competencies in written work which hitherto was a major challenge of both interdisciplinarity and evaluation, thereby setting a tone for future endeavors in using written work to assess student learning progress. In addition, confirming that integration has taken place especially in written work or interdisciplinary endeavor was resolved to a large extent in this study, thereby laying a good foundation for future research on evaluating integration and other related competencies. Moreover, review of student written submissions and the lack of demonstration of some evidence of learning outcomes observed in this study serves as a great insight into the disjoint that exists between learning program goal expectation and what is eventually learned or actually measured. This leaves a lot of gaps in assessment studies and this disjointedness may be explained by outright inability to transform learning into outcomes i.e., "learners did not learn" or poor and inadequate assessment, evaluation of the outcomes i.e., "learners learned, but outcomes could not be demonstrated and measured". The inadequacy in assessment or evaluation may also be due to instrumentation deficiency or poor construct definition or the way the items are framed. This study attempted to make provision for the above to ensure adequate capture of the competencies. Further research into this could help in bridging this gap between learning and proficiency. In addition to the above, there must be concerted effort at ensuring that learners and teachers are trained on how to demonstrate integration, collaboration and critical thinking and their indicators in writing assignments. Up until now, as this study has also revealed, the competencies seem to confirm the difficulty to capture or present them in a written work. While most research outputs are disseminated via written evidence, then researchers and learners everywhere would be shortchanging their innovations as long as they have not found viable means to project their integrated competencies in their written work.

5.6 Limitations of the study

The strengths of this study include obtaining samples of submitted capstone projects over the span of years of the program. Up to this point, this is one of the few studies that has evaluated the interdisciplinary competencies in occupational safety and health of students from the submitted written capstone projects of this program and utilized the sample from different years of the program. Additionally, this study, beyond developing a rubric proceeded to calibrate the rubric using Rasch analysis, which allowed for confirming the validity and reliability of the rubric for use on occupational safety and health, other ERCs and competency-based training programs. The calibration thus presents an item format that offer users a consistent scale and reduce potential irritation provoked by changing response options and item polarity. Also, the initial item selection was elaborate and would cover a broader spectrum. The iCER-OSH thus offers the field of evaluation and interdisciplinarity, a rubric to prepare teachers and students a transparent competencies expectation of both learning outcomes and outputs relevant for both formative and summative assessment. Thus, the competency and proficiency challenge of learning outcomes is to a large extent resolved by iCER-OSH rubric.

Overall, from the author's experience as a student in and outside of the US, and in interaction with other students have always been bewildered at teachers' expectation and what relevance the theories and principle learned has to real life, this myth gets worse when the concepts have some abstraction and are not easily related to any life issues at face value. The indicators of the iCER-OSH rubric would therefore be an insight into this mystery and offer students the transparent expectation life skills and practical applications of the program learning objectives. This for the program and the field of evaluation would be a great output.

A key limitation to this study starts with the small sample size (n=35 capstone projects). Also, the method of grading the capstone projects where each is reviewed through the lens of each indicator. A more valid outcome would be holistic and sequential review by chapters using the instrument. Also, one-rater who is also the writer of the items is a huge limitation to this study as this portends a lot of subjectivity and introduction of systematic error. A possible remediation is the suggestion of multiple raters as recommended. In addition, the lack of access to other activities of students on the CARERC program, especially the activities used in complimentary assessment of the students like field activities, seminars and other on-site assessments. These significant other activities and the capstones could have made up for the evidenced poor visibility of some competencies and indicators in the submitted written capstones of the students on the program. Also, getting the perspectives of the students on the CARERC program and views of the teachers on interdisciplinary competencies in OSH would have enriched this study, hence these may be considered in future research. Another limitation to this study is the small sample size used in this study, this would prevent generalizability of the outcome of this study.

Although this study had some limitations including the possible misclassification of competencies, results of this study add support to the growing body of evidence on interdisciplinary competencies especially in occupational safety and health and rubric development in evaluation. This study serves as a justification for further research into foundational core and specific interdisciplinary competencies in occupational safety and health coupled with how these may influence the orientation of the competencies in future frameworks.

APPENDICES

APPENDIX 1. PARAMETER AND CODING TABLE

Parameter	indicator	Coding Key
Dept	Occupational Epidemiology	1
	Agricultural Health & Safety (Environmental Health)	2
	Occupational Epidemiology	1
	Mining and Health Safety	3
	Occupational Safety	4
	Occupational & Environmental Health Nursing	5
Program	DPH	1
	MPH_Ag	2
	MPH_Oc	3
	MS_Mi	4
	MS_Oc	5
	PhD	6
Item	Yes	1
	No	0

APPENDIX 2. PERCENTAGE OF PRESENCE OF INTERDISCIPLINARY COMPETENCIES IN OSH IN CARERC CAPSTONE PROJECTS

S/N	Item		% Presence	
1	**Integration**		**Yes**	**No**
a	The capstone project reveals it is designed to reflect consideration of relevant activities based on multiple methods	Integ_a	82.90	8.60
b	The capstone project reveals it is designed to implement new health promotion processes based on multiple methods	Integ_b	5.70	94.30
c	The capstone project reveals it formulated new guideline(s) based on multiple methods	Integ_c	0.00	100.00
d	The capstone project reveals it formulated new policy(ies) based on multiple methods	Integ_d	5.70	94.30
e	The capstone project reveals it created a new culture of wellness in the workplace based on multiple methods	Integ_e	0.00	100.00
f	The capstone project reveals it created a new surveillance process in the workplace based on multiple methods	Integ_f	2.90	97.10
g	The capstone project reveals it incorporated data from more than one disciplines	Integ_g	82.90	17.10
h	The capstone project reveals it offered recommendations for future intervention(s)	Integ_h	100.00	0.00
1	**Collaboration**			
a	The capstone project reveals it identified specific personnel gap in the execution of the project	Colab_a	25.7	74.30
b	The capstone project reveals it managed staff/personnel resources used in the project effectively	Colab_b	8.60	91.40

c	The capstone project reveals it displayed effective leadership over multiple team members/activities	Colab-c	5.70	94.30
d	The capstone project reveals it functioned effectively on a team of more than one disciplines	Colab_d	11.40	88.60
e	The capstone project reveals it demonstrated attention to thoroughly describing the approach for fulfilling work interaction among peers	Colab_e	14.30	85.70
f	The capstone project reveals it incorporated data from more than one sources	Colab_f	88.60	11.40
g	The capstone reveals it utilized secondary data	Colab_g	82.90	17.10
3	**Creative Thinking**			
a	The capstone project reveals it designed project activities on multiple methods	Creative_a	71.40	28.60
b	The capstone project reveals it implemented project activities on multiple methods	Creative_b	88.60	11.40
c	The capstone project reveals it designed screening activities based on multiple methods	Creative_c	51.40	48.60
d	The capstone project reveals it implemented screening activities based on multiple methods	Creative_d	42.90	57.10
e	The capstone project reveals it designed surveillance activities based on multiple methods	Creative_e	22.90	77.10
f	The capstone project reveals it implemented surveillance activities based on multiple methods	Creative_f	17.10	82.90
g	The capstone project reveals it implemented a well-designed health promotion and education programs	Creative_g	2.90	97.10
h	The capstone project reveals it implemented a well-designed work process interventions built on more than one disciplinary	Creative_h	5.70	94.30

	approach			
i	The capstone project reveals it developed health and safety programs	Creative_i	5.70	94.30
j	The capstone project reveals it implemented health and safety programs	Creative_j	11.40	88.60
k	The capstone project reveals it applied best practices to optimize sustainable activity(ies) plan	Creative_k	22.90	77.10
l	The capstone project reveals it looked for unexamined linkages in project activities	Creative_l	100.00	0.00
m	The capstone project reveals it looked for unexpected effects in project activities	Creative_m	100.00	0.00
4	**Communication**			
a	The capstone project demonstrates that it communicates effectively with a variety of stakeholders (e.g, management, labor)	Comm_a	22.90	77.10
b	The OSH opinion presented in the capstone project is clear to understanding	Comm_b	100.00	0.00
c	The capstone project demonstrates that it writes well to pass its opinion in a concise way	Comm_c	100.00	0.00
d	The capstone project demonstrates that it interprets policies clearly	Comm_d	100.00	0.00
e	The capstone project demonstrates that it disseminates policies clearly	Comm_e	100.00	0.00
f	The capstone project demonstrates that it discusses effectively with other safety and health professionals	Comm_f	22.90	77.10

APPENDIX 3. CARERC PROGRAM CORE SYLLABI

UNIVERSITY OF KENTUCKY
COLLEGE OF PUBLIC HEALTH

Course Syllabus
CPH 620-401 Occupational & Environmental Health II
Spring 2018

College of Public Health Building (Research Facility 1) – Room 207 111 Washington Avenue
Building Number 3 on Campus Map
http://maps.uky.edu/campusmap/
Wednesday 6 pm to 8:30 pm

Contact Information

Instructor: Wayne T. Sanderson, PhD, CIH
College of Public Health Room 355 – Bowman Hall 151 Washington Avenue
Lexington, Kentucky 40506
http://ukcc.uky.edu/cgi-bin/dynamo?maps.391+campus+0059

Telephone: (859) 218-2227

E-mail: wayne.sanderson@uky.edu

Office Hours: By Appointment

Course Description

CPH 620 addresses advanced theories and practices of identifying, assessing, and controlling occupational and environmental hazards that may adversely affect the health of communities and working populations. The course emphasizes harmful effects of non-chemical hazards, such as radiation, noise, hypoxia, and physical agents that lead to morbidity and mortality.

However, evaluation and control measures will cover many types of hazardous exposures, including those from chemical exposures.

Course Rationale:

The course covers a wide cross-section of occupational and environmental health and safety problems. It is designed primarily as an introduction to occupational health and safety for graduate students in industrial hygiene, environmental health, engineering, occupational health nursing, ergonomics, injury prevention, agricultural health, safety, occupational epidemiology, and Occupational Medicine Residents. Topics that will be covered include: health effects of exposures chemical, physical, and biologic agents; anticipation, recognition, evaluation, and control of workplace hazards; screening and disease prevention; basic principles of industrial hygiene, occupational medicine, occupational safety, occupational health nursing and ergonomics; legal and regulatory issues; evaluation and control of health risks in the workplace; ethics in occupational health; and special populations at risk for occupational disorders.

This course relates directly to the accomplishment of the educational program goals for the MPH, DrPH, and PhD degrees and completion of the Occupational Medicine and Preventive Medicine Residency training programs in the University of Kentucky, College of Public Health.

Course Prerequisites

Environmental Health (CPH 601) is required.

Biostatistics I (CPH 570 or 580) is recommended before taking this course, but is <u>not</u> required.

Course Objectives/Student Learning Outcomes and Related UKCPH Competencies

Program Level Outcomes	Course/Student Learning Outcomes
• MPH SLO (1): Propose solutions for public health problems using sound data analysis and evidence-based decision making • MPH SLO (2): Demonstrate cultural competency in public health through transdisciplinary communication and collaboration • MPH SLO (3): Evaluate program planning, ethical and professional strategies in public health • MPH SLO (4): Create novel approaches to health systems and systems thinking • MPH SLO (5): Integrate advocacy and public health knowledge within core public health areas	Students will gain experience in interdisciplinary problem-solving in occupational and environmental health. Students will improve and use skills as active learners. Students should be able to take an occupational health problem, independently search the literature to find relevant materials, and then synthesize the information obtained. Students should be able to review the assigned readings and to find the most important issues in them. Students will understand the legal and regulatory environment in which occupational health operates. They should have an understanding of the social and economic as well as labor-management influences that can affect issues of health in the workplace. Students will be familiar with the ways in which health risks in the workplace can be anticipated, recognized, evaluated and controlled. They should understand the strategies and methods available for evaluation, and know their limitations and constraints. They should understand the hierarchy of engineering controls, administrative controls, and personal protective controls. They should be familiar with the basic technical aspects of engineering controls and personal protective controls. Students will be familiar with a wide range of occupational disorders and understand the relationship between workplace exposures and health effects.

	Students will understand the basic principles of occupational medicine, industrial hygiene, occupational health nursing, occupational safety, and ergonomics.

Textbooks and Other Materials

The following textbooks are required for this course:

ACGIH, 2017 TLVs and BEIs, ACGIH Signature Publications, 2016. A copy of this book—or a recent version--will be provided to the students for the duration of the semester and is necessary for completing the Problem Sets.)
http://www.acgih.org/store/ProductDetail.cfm?id=2233

The following supplemental texts may also be useful. They are not required, but may be instructive for those health professional students who want more in-depth knowledge of the occupational diseases.

Rosenstock L, Cullen, Mark, Brodkin C, Redlich C. *Clinical Occupational and Environmental Medicine*, 2nd edition; Philadelphia; Elsevier Saunders 2005.

Rom W, Ed. *Environmental and Occupational Medicine*, Fourth Edition. 2007. Wolters Kluwer/Lippincott Williams & Wilkins.

Levy BS, Wegman DH, Baron SL, Sokas RK. *Occupational Health: Recognizing and Preventing Work-Related Disease*, 6th edition; Oxford Press 2011.
http://www.amazon.com/Occupational-Environmental-Health-Recognizing-Preventing/dp/0195397886

Required readings from journal articles, manuscripts, and other documents are will be posted in the online component (Blackboard) of the course.

Course Requirements and Learner Evaluation

The course will consist of lecture/discussion classes and self-study. The course will be enhanced by an online component in Canvas which will provide resources for accessing class materials including assignments and readings.

Course grades will be based upon evaluation of the following activities:

Assignments and Tests	Points
Homework Problem Sets: 6 at 50 points each	300
Mid-Term Examination	100
Final Examination	100

TOTAL	500

Letter grades for the course will be assigned on a percentage basis (as given below) for the student's total score as a percentage of the total number of points possible for the course.

Grade	%	# Points
A	90-100	>450
B	80-89	400 – 449
C	70-79	350 – 399
E	≤ 69	<350

Instructor Expectations

- Students enrolled in the class are required to participate in discussions during class meetings. This requires that he/she is well prepared in having read the assigned literature and has completed homework assignments or other activities for generating discussion.
- Presentation of major issues, controversies, or basic information on a wide variety of diseases will be presented to the class. However, most of the classroom time will be spent in interactive discussion and professor questioning and student answering.
- The problem set assignments involve applied computations relevant to occupational health and safety and short answers of conceptual questions. Problem sets will generally be assigned such that students have at least one week to complete them.
- The assignments must be the students' own work (i.e. each student must turn in a completed assignment), but students are encouraged and allowed to work together in solving the problems and assisting each other with the exercises.
- Assignments are to be submitted using proper English grammar, syntax, and spelling. You are encouraged to use spell check and grammar check prior to submitting your written work.
- Students are encouraged to provide honest and timely feedback regarding the content and process of this course throughout the semester.

Academic Policies

It is the student's responsibility to be informed concerning all regulations and procedures required by the program of study, College or the University. Students should become familiar with the Undergraduate Bulletin or the Graduate School Bulletin as appropriate. Academic disputes will be evaluated against these policies. This serves as formal notification of academic policies.

Students and faculty can locate the College of Public Health and University policies at: http://www.uky.edu/publichealth/student-resources/academic-policies

Policies that are available include:

- Academic Integrity
- Accommodations Due to Disability
- Religious Observances
- Inclement Weather
- Excused Absences Policy
- Verification of Absences
- Student Resources

A hard copy of the policies will be provided by the Office of Academic Affairs upon request by the student.

Late Work Policy

Students are expected to take examinations or turn in assignments on the date and time scheduled by the instructor. Students who cannot take the examination on the scheduled day must have an excused absence as defined in the *Student Rights and Responsibilities* handbook. Students should inform the faculty in advance of the examination if a problem exists with respect to taking the exam on the designated day. Students will be given the opportunity to make up missed work or exams. Students are entitled to excused absences for the purpose of observing their major religious holidays. If assignments are not turned in before they have returned to other students, the students will be penalized for turning in work late (2 to 8 points depending upon the degree of lateness).

Course Schedule and Topics

Class	**Month**	**Date**	**Topic**	**Problem Set Due**
1	Jan	10	Introduction Orientation / History of Occupational Safety and Health Laws and Regulations	
2	Jan	17	Recognizing and Evaluating: Gases and Vapors and Dusts	
3	Jan	24	Recognizing and Evaluating Bioaerosols, Skin Exposures, Biological Monitoring	**Problem Set #1**

4	Jan	31	Recognizing and Evaluating: Physical Agents	
5	Feb	7	Controlling Hazards Personal Protection	**Problem Set #2**
6	Feb	14	Occupational Injuries and Safety Workers Compensation	
7	Feb	21	Occupational Ergonomics Musculoskeletal Disorders	**Problem Set #3**
8	Feb	28	Evaluating a Worksite Preliminary Hazard Analysis	
9	Mar	7	**Midterm Examination** / Field Trip Preparation	
--	Mar	14	No Class – Spring Break	
10	Mar	21	Occupational Cancers	
11	Mar	28	Occupational Respiratory Diseases	**Problem Set #4**
12	Apr	4	Occupational Cardiovascular and Hematologic Disorders (Dr. Spengler)	
13	Apr	11	Occupational Skin and Eye Disorders Neuropsychological Disorders (Dr. Prince)	**Problem Set #5**
14	Apr	18	Occupational Reproductive, Kidney, Liver Disorders	
15	Apr	25	Occupational Safety and Health Professions Review for Final Examination	**Problem Set #6**
--	May	2	**Final Examination at regularly scheduled class time period (6-8:30 pm) in the usual Classroom 207**	

The lecture schedule and due dates for the Problem Sets are subject to change depending on the schedules of faculty and the progress of the course. Students will be given notice in the event of a change in the schedule.

UNIVERSITY OF KENTUCKY
COLLEGE OF PUBLIC HEALTH

Course Syllabus
CPH 698-001 Occupational Safety & Health Field Surveys
Spring 2018

The Field Studies course is offered during the Spring semester
Various worksites in the Central Appalachian Region will be visited on the dates and times pre-arranged with the host worksites
Most site visits will take place during Spring Break

Contact Information

Instructor: Wayne T. Sanderson, PhD, CIH
College of Public Health Room 355 - Bowman Hall 151 Washington Avenue
Lexington, Kentucky 40506

Telephone: (859) 218-2227

E-mail: wayne.sanderson@uky.edu

Office Hours: By Appointment

Course Description

The course provides students the opportunity to visit various work sites and industries in the Appalachian region. Students are provided on-site, direct experience recognizing hazards and evaluating control measures to reduce occupational health and safety risks across of wide spectrum of industry sectors. The students will employ knowledge and skills obtained in other courses to successfully recognize and assess the hazards associated with various work practices and industrial processes. Students evaluate the hazard monitoring and implementation of control measures to reduce workers' health and safety risks.This is a cross- disciplinary course for graduate students in occupational safety, industrial hygiene, environmental health, occupational health nursing, ergonomics,

injury prevention, agricultural health and safety, occupational epidemiology and occupational medicine.

Course Rationale:

This course relates directly to the accomplishment of the educational program goals for the MPH, MS, DrPH, and PhD programs which are subsumed in the training program for the Central Appalachian Regional Education and Research Center. The goals and objectives for specific degree programs which form the core disciplines in the ERC (agricultural health and safety, nursing, occupational epidemiology, mining engineering, occupational safety and health) are described in the respective student handbooks in these programs.

Course Prerequisites

Occupational and Environmental Health II (CPH 620)
Course Objectives/Student Learning Outcomes and Related UKCPH Competencies

Program Level Outcomes	**Course/Student Learning Outcomes**

• MPH SLO (3): Evaluate program planning, ethical and professional strategies in public health • MPH SLO (4): Create novel approaches to health systems and systems thinking • MPH SLO (5): Integrate advocacy and public health knowledge within core public health areas • DrPH SLO (5): Generate evidence-based communication for professionalism, advocacy and leadership within core public health areas • PhD EPB SLO (1): Demonstrate systems thinking using epidemiology theory and concepts and through data collection, analysis, interpretation, evidence-based reasoning • PhD EPB SLO (2): Analyze data and research methods using biostatistics theory and concepts • PhD EPB SLO (4): Communicate inter- professionally regarding study management processes, problem conceptualization, ethics and core public health knowledge	After completion of this course the student will: 1. Be able to identify an occupational health problem, independently search the literature to find relevant materials, and then synthesize the information obtained. 2. Be familiar with approaches to anticipating, recognizing, evaluating, and controlling workplace health risks. 3. Understand the legal and regulatory environment in which occupational health operates. This includes an understanding of the social and economic as well as labor-management influences that can affect issues of health in the workplace. 4. Become familiar with the hierarchy of engineering controls, administrative controls, and personal protective controls. They should be familiar with the basic technical aspects of engineering controls and personal protective controls. 5. Be familiar with a wide range of occupational disorders and understand the relationship between workplace exposures and health effects.

Worksites visited will include some of the following types of workplaces: underground and surface coal mines, rock quarries, oil refineries, chemical plants, asphalt paving and roadway construction, sawmills, timber harvesting, truck and rail terminals, automobile manufacturing, food production, cattle, poultry, and grain farms, small manufacturing companies, hospitals, and law enforcement investigation sites.

Topics that will be covered include: health effects of exposures; anticipation, recognition, evaluation, and control of workplace hazards; screening and disease prevention; basic principles of industrial hygiene, occupational medicine, occupational safety, occupational health nursing and ergonomics; legal and regulatory issues; evaluation and control of health risks in the workplace; ethics in occupational health; and special populations at risk for occupational disorders.

Students will be familiar with the ways in which health risks in the workplace can be anticipated, recognized, evaluated and controlled.

They should understand the strategies and methods available for evaluation, and know their limitations and constraints. They should understand the hierarchy of engineering controls, administrative controls, and personal protective controls.

They should be familiar with the basic technical aspects of engineering controls and personal protective controls.

Students will be familiar with a wide range of occupational disorders and understand the relationship between workplace exposures and health effects.

Students will understand the basic principles of occupational medicine, industrial hygiene, occupational health nursing, occupational safety, and ergonomics.

Textbooks and Other Materials

The following textbook is required for this course:

ACGIH, 2017 TLVs and BEIs, ACGIH Signature Publications, 2017. A copy of this book—or a recent version--will be provided to the students for the duration of the semester and is necessary for completing the Problem Sets and Hazard Evaluation.) http://www.acgih.org/store/ProductDetail.cfm?id=2233

Required readings from journal articles, manuscripts, and other documents are will be posted in the online component (Canvas) of the course.

Appropriate OSHA standards and NIOSH criteria will also be assigned.

Course Structure

This is a field studies course. Consequently, the schedule, the locations, and the particular work sites and locations visited may be subject to change based upon weather, availability of sites, permissions required, and other scheduling concerns. Some worksites will be located within a two hour drive from Lexington, Kentucky, while other worksites will be located several hours from the campuses of University of Kentucky and Eastern Kentucky University; overnight stays will be required for visiting these worksites and transportation and lodging will be provided for students to travel to these worksites. (Note: students will be required to complete the attached motor vehicle release form before traveling to the worksites.) We have structured the course with at least one extended trip and several short day trips to complete visits to a diversity of worksites.

1. Initially, visits to each worksite will include discussions with management and labor concerning operating procedures, occupational health and safety issues, standards, recording keeping, specific work tasks, work organization, and the health and safety

culture.

2. Students will take a supervised tour of the worksite. Interdisciplinary teams will be formed before each tour and the teams will be required to focus on specific health and safety problems identified by company management. During the tour, students will evaluate health and safety procedures associated with selected work tasks. The students will have the opportunity to interview workers and observe them conducting the tasks.

3. After the tours are completed, the students and faculty will meet to discuss the plant tour(s) that took place that day, highlighting the health and safety issues associated with the workplace and the company's approach to dealing with the problems.

4. Students will subsequently carry out a literature search on an occupational health and safety problems to which they were assigned to evaluate.

5. Students will be responsible for working in multidisciplinary teams to conduct a hazard analysis of their assigned health and safety concern. Each team will be required to submit a report (approximately10 pages) that summarizes their activities, observations, and recommendations for the worksites. This exercise will be graded by the Field Survey course faculty team. The hazard analysis reports are to be submitted via e-mail to Dr. Sanderson approximately four weeks after the field survey. Each worksite will also have problems sets associated with them that are to be completed and turned in by each student to Dr. Sanderson.

Course Requirements and Learner Evaluation

Grades will be determined as follows:

Assignments	Points
Five site visit/hazard analysis Problem Sets: 50 points each	250
Site visit participation and discussion (10 points per site)	50
Team Hazard Evaluation Report and Presentation	100
TOTAL	**400**

Letter grades for the course will be assigned on a percentage basis (as given below) for the student's total score as a percentage of the total number of points possible for the course.

GradePoints	%

A	360 – 400	90-100
B	320 – 359	80-89
C	280 – 319	70-79
E	279 or below	<= 69

Instructor Expectations

1. Students are expected to attend every class/worksite session. The components are highly interrelated; missing a class will detract from the learning potential of subsequent sessions.
2. Students are expected to actively participate in the discussions. This is not the type of class where you can "sit back and listen."
3. Reports are to be submitted proper English grammar, syntax, and spelling. Students are encouraged to use spell check and grammar check prior to submitting your written work.
4. Students are expected to provide honest and timely feedback regarding the content and process of this course.
5. Students are expected to interactively engage with the other students and the instructor.
6. The problem set assignments involve applied computations relevant to occupational and environmental health and safety and short answers of conceptual questions. The assignments must be completed and handed in on the due date.
7. The assignments must be the students' own work (i.e. each student must turn in a completed assignment), but students are encouraged and allowed to work together in solving the problems and assisting each other with the exercises.

Academic Policies

It is the student's responsibility to be informed concerning all regulations and procedures required by the program of study, College or the University. Students should become familiar with the Undergraduate Bulletin or the Graduate School Bulletin as appropriate. Academic disputes will be evaluated against these policies. This serves as formal notification of academic policies.

Students and faculty can locate the College of Public Health and University policies at: http://www.uky.edu/publichealth/student-resources/academic-policies

Policies that are available include:

- Academic Integrity
- Accommodations Due to Disability
- Religious Observances
- Inclement Weather
- Excused Absences Policy

- Verification of Absences
- Student Resources

A hard copy of the policies will be provided by the Office of Academic Affairs upon request by the student.

Late Work Policy

Students are expected to take the examinations or turn in exams on the day scheduled in the syllabus. Students who cannot take the examination on the scheduled day must have an excused absence (illness of student or family member, death of family member, university sponsored trip, etc.) as defined in the *Student Rights and Responsibilities* handbook. Students should inform the faculty in advance of the examination if a problem exists with respect to taking the exam on the designated day. Students will be given the opportunity to make up missed work or exams in the event of excused absences. Students are entitled to excused absences for the purpose of observing their major religious holidays. If assignments are not turned in before they have returned to other students, the students will be penalized for turning in work late (2 to 8 points depending upon the degree of lateness).

Motor Vehicle Record (MVR) Release and Information Form

Please provide all requested information and return form to UK Risk Management

UK Risk Management
306 Peterson Service Building Lexington, KY 40506-0005
Phone: (859) 257-3708 Fax: (859) 257-1050

Please attach copy of Drivers' License here.

Department Information:

UK Department: _______________ Department Number: ________________________________

Driver Information: _____ _____

Exactly as it appears on Drivers' license

Address: ____City: ______ ST: ______ Zip: ______

Sex:__ Date of Birth: _______________________

Drivers License Number: ________________________________ State:

Years Driving Experience Yrs:___________Mos: ____________ Hire:____ Date of

In connection with any application made by me, I understand that investigative background inquiries may be made on me concerning matters of motor vehicle information. I understand that you may be requesting information from various Federal, State, and other agencies which maintain records concerning past activities relating to my driving records.

I authorize, without reservation, any party or agency contacted to furnish the above mentioned information and release all parties involved from any liability and/or responsibility for doing so. I hereby consent to the University of Kentucky to obtain such information from Sonic e-Learning Inc. and/or any of their agents. This authorization and consent shall be valid in an original, fax or copy form. I

recognize that these inquiries may be made randomly in the future and no further authorization is required by me.

Failure to provide all information requested may result in a delay of UK driving privileges.

Driver's Signature: X Date:

Risk Management Department Use

UNIVERSITY OF KENTUCKY
COLLEGE OF PUBLIC HEALTH

Course Syllabus
CPH 716-001 ProSeminar Occupational Health and Safety
Fall 2018

Location: **The course will meet at various locations on the UK and EKU campuses or worksites within an hour's drive from Lexington, KY.**
Fridays: **12:00pm – 2:50pm**

Contact information for Core Faculty

Ellen Hahn, PhD College of Nursing Room 519
859-257-2358
ejhahn00@email.uky.edu

Steven R. Browning, PhD College of Public Health Room 209B
859-218-2235
srbrown@uky.edu

Wayne Sanderson, PhD
Director, CARERC
College of Public Health Room 355 Bowman Hall 859-218-2227
wsa223@uky.edu

Joseph Sottile, Ph.D. College of Engineering Mining Engineering - MNG 234A MMRB
Phone: 859-257-4616
joseph.sottile@uky.edu

Scotty Dunlap , Ed.D., CSP
Eastern Kentucky University

School of Safety, Security and Emergency Management Room: Stratton 345C
Mailing Address: Stratton 250 Phone: (859)622-7208
scotty.dunlap@eku.edu

Office Hours: There are no specific office hours, but students are welcome to arrange in person meetings with ERC Core Directors by telephone or e-mail as needed.

Course description

This course will provide students, in a seminar format for 5 sessions during the semester, presentations from occupational health and safety professionals from a variety of disciplines and experiences. The seminar is approximately 3 hours long at each session for a total of 15 semester contact-hours. Topics regarding workplace exposures and related health outcomes will be presented and discussed. Students should acquire basic understanding of current topics in the fields of occupational medicine, nursing, safety, industrial hygiene, epidemiology, biostatistics, mining, and agriculture.

Course rationale:

This course will provide students, presentations from occupational health and safety professionals from a variety of disciplines and experiences. Knowledge and skills regarding workplace exposures and related health outcomes will be developed in this inter-professional course.

This course relates directly to the accomplishment of the educational program goals for the MPH, MS, DrPH, and PhD programs which are subsumed in the training program for the Central Appalachian Regional Education and Research Center. The goals and objectives for specific degree programs which form the core disciplines in the ERC (agricultural health and safety, nursing, occupational epidemiology, occupational medicine, mining engineering, occupational safety and health) are described in the respective student handbooks in these programs.

Course prerequisites

None

Credit

For completion of educational requirements of the Central Appalachian Regional Education and Research Center (CARERC) students must enroll in the seminar for four semesters. The students will receive 0 credit for three semesters and 1 credit hour for one semester. During the semester that students take the ProSeminar for credit, they must provide a formal seminar presentation. Other (non-CARERC) students may also take the seminar once for 1 hour credit.

Course structure

The course will consist of six seminars during the semester in the format of a lecture, discussion section, debate, lab or problem exercise, or field survey. Course materials may be provided by an online component in Canvas. Students will be required to actively engage in the seminar through discussion and questioning of presenters. The students will be required to lead at least one seminar session (when course is taken for credit) discussing the particular occupational safety and health problem they have been studying. This presentation will usually be regarding their capstone, thesis, or dissertation topic.

Course Objectives/Student Learning Outcomes and related UKCPH Competencies

Program Level Outcomes	**Course/Student Learning Outcomes**

1. PhD EPB SLO (2): Analyze data and research methods using biostatistics theory and concepts 2. PhD EPB SLO (4): Communicate inter-professionally regarding study management processes, problem conceptualization, ethics and core public health knowledge	After completion of this course in the student will be: 1. Familiar with occupational safety and health problems in the workplace and understand practical solutions to those problems being employed by professionals. 2. Have knowledge of research being conducted to answer important occupational safety and health problems. 3. Appreciate the issues associated with study design and research methods for conducting occupational health and safety research. 4. Discuss and communicate issues concerning of occupational safety and health problems and potential solutions to those problems. 5. Evaluate the occupational and environmental epidemiologic literature in a systematic and critical manner for assessing disease and injury associations and assessing risks.

Textbooks and Other Materials

Course materials will be distributed either email, Canvas, or as handouts in class. The materials will contain a topic schedule for the course and a listing of the reading assignments. There is no required text for the class.

Required readings from journal articles, manuscripts, and other documents are listed in the daily assignments. Most of the journal articles for readings will be available as electronic documents in Canvas. Students are responsible for securing their own copies of the readings and reviewing the materials prior to the class.

Course requirements and learner evaluation

Course grades will be based upon evaluation of the following activities:

Criteria	Points
Attendance: 5 sessions, 10 points per session	50
Class participation: 5 sessions, 10 points per session	50

Technical presentation. • Scientific and technical aspects of research project (40 points) • Slides, graphics, and presentation clarity (40 points) • Oral delivery / clarity in addressing questions (20 points)	100
TOTAL	200

The technical presentation is considered the final exam and final project for the ProSeminar course and is undertaken on the last scheduled seminar date for the semester.

Letter grades for the course will be assigned on a percentage basis (as given below) for the student's total score as a percentage of the total number of points possible for the course. In accordance with the Graduate School Bulletin, grading for the course will use the grading scale of the Graduate School. D grades may not be awarded to graduate students. The incomplete grade ("I") is intended only for students who are not able to complete the assigned course work on schedule due to serious illness or other highly unusual personal circumstances.

Grade	Definition	%	Points
A	High Achievement	90-100	180 – 200
B	Satisfactory Achievement	80-89	160 – 179
C	Minimum Passing grade	70-79	140-159
E	Failure	< = 69	<=139

Instructor expectations

1. I expect you to attend every class session. The components are highly interrelated; missing a class will detract from the learning potential of subsequent sessions.

2. I expect you to be in the classroom and prepared to begin work at the scheduled starting time for each session.
3. I expect you to actively participate in the discussions. This is not the type of class where you can "sit back and listen."

4. I expect (and encourage) you to provide honest and timely feedback regarding the content and process of this course throughout the semester.
5. I expect you during the semester to interactively engage with the other students and the instructor.
6. I expect you to share in the responsibility for making this course an enjoyable and beneficial learning experience.

4

Academic Policies

It is the student's responsibility to be informed concerning all regulations and procedures required by the program of study, College or the University. Students should become familiar with the Undergraduate Bulletin or the Graduate School Bulletin as appropriate. Academic disputes will be evaluated against these policies. This serves as formal notification of academic policies.

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http://www.uky.edu/publichealth/student-resources/academic-policies

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- Verification of Absences
- Student Resources

A hard copy of the policies will be provided by the Office of Academic Affairs upon request by the student.

Late work policy

It is expected that you will attend and participate in all class seminar during the semester. Please contact the instructor in advance if you cannot attend. The instructor will work with you to provide an opportunity to attend a comparable or related presentation (such as the CPH Grand Rounds series) to make up for the session missed. You are expected to

present the results of your research in this seminar during the semester that you are taking the course for credit. Credit will only be awarded if the presentation is made.

<u>Seminar Schedule.</u>

Class	**Month**	**Dat**	**Topic**	**Faculty/Location**
1	August	31	**Course Orientation Temporary Workers: Film "A Day's Work**	CON 501c
2	September	21	**Steven Lacy, PhD: Lasers and NonIonizing Radiation Hazards**	CPH 207
3	October	12	**Brian Curwin, PhD: MesoAmerican Nephropathy**	CON 501c
4	November	9	**Scotty Dunlap, EdD: Grain Handling Safety and Health Hazards**	EKU Stratton Hall
5	December	7	**Presentations by Graduating CARERC students.**	Location TBA

UNIVERSITY OF KENTUCKY
COLLEGE OF PUBLIC HEALTH

Course Syllabus
CPH 720-001 Health of Agricultural Populations Fall 2018

College of Public Health Building (Research Facility 1) – Room 202 111 Washington Avenue
Building Number 3 on Campus Map
http://maps.uky.edu/campusmap/

Tuesday, Noon to 2:30 pm

Contact Information

Instructor: **Wayne T. Sanderson, PhD, CIH**
College of Public Health 355 Bowman Hall
151 Washington Avenue
Lexington, Kentucky 40506
Telephone: **(859) 218-2227**
E-mail: **wayne.sanderson@uky.edu** **Office Hours: By Appointment**

Instructor: **Stacy Vincent, PhD**
Associate Professor, Extension: Community and Leadership Development
505 Garrigus Building
Lexington, KY 40506
Telephone: **859-257-7588**
E-mail: **stacy.vincent@uky.edu**
Office Hours: By Appointment

Instructor: **Laura Rice, PhD**
Assistant Professor, Extension: Community and Leadership Development
714 Garrigus Building
Lexington, KY 40506
Telephone: **814-553-0324**

E-mail:
**l aurarice@uky.ed u Office Hours:
By Appointment**

Course Description

Health of Agricultural Populations **addresses the threats and hazards that impact the health, safety and productivity of farmers, members of farm families, hired farm workers, and others who live or work in agricultural environments, such as crop and livestock production, timber production and commercial fishing. This course offers analysis in selected issues of agricultural health and safety. Students will visit agricultural operation sites.**

Course Rationale

The course covers a wide variety of agriculture safety and health problems faced by agricultural and rural populations. Students learn to recognize agricultural population exposures to hazardous health and safety situations and the injuries and diseases that can result from these exposures. The students will also learn intervention strategies to reduce the risk from hazardous exposures. The course is particularly designed for training graduate students in agriculture, safety, industrial hygiene, environmental health, engineering, occupational health nursing, ergonomics, injury prevention, occupational epidemiology, and Occupational Medicine Residency. Topics covered include: health effects of exposures to chemical, physical, and biologic agents; anticipation, recognition, evaluation, and control of agricultural hazards; screening and disease prevention; basic principles of industrial hygiene, occupational medicine, legal and regulatory issues in agriculture; evaluation and control of health risks in the agricultural environment; ethics in access to care and providing of prevention services; and special populations at risk for agricultural injuries and diseases.

This course relates directly to the accomplishment of the educational program goals for the MS, MPH, DrPH, and PhD degrees and completion of the Occupational Medicine and Preventive Medicine Residency training programs in the University of Kentucky, College of Public Health.

Course Prerequisites

None

Course Objectives/Student Learning Outcomes and Related UKCPH Competencies

UKCPH Competencies	**Course/Student Learning Outcomes**
MPH Competencies 1. Assess population-based health problems from the perspective of multiple public health science disciplines. 2. Propose potential solutions to public health problems based on an understanding of systems theory, essential services, and social, behavioral, environmental, and biological factors that contribute to the problem. 3. Use basic terminology and definitions of epidemiology. 4. Identify key sources of data for epidemiologic purposes. 5. Calculate basic epidemiologic measures and draw appropriate inferences. 6. Use evidence based principles and scientific knowledge effectively when involved in evaluation and decision-making in public health. 7. Assess public health problems in terms of magnitude, person, time and place. 8. Evaluate the strengths and limitations of epidemiologic reports. 9. Identify the principles and limitations of public health screening programs. 10. Describe the federal and state regulatory programs, guidelines, and authorities that control public health.	Students will gain experience in interdisciplinary problem-solving in agricultural health and safety. Students will improve and use skills as active learners. Students should be able to take an agricutural health or safety problem, independently search the literature to find relevant materials, and then synthesize the information obtained. Students should be able to review the assigned readings and to find the most important issues in them. Students will understand the legal and regulatory environment in which agricultural health and safety operates. They should have an understanding of the social and economic as well as labor- management influences that can affect issues of health in the agricultural environment. Students will be familiar with the ways in which health risks in the agricultural and rural environment can be anticipated, recognized, evaluated and controlled. They should understand the strategies and methods available for evaluation, and know their limitations and constraints. They should understand the hierarchy of engineering controls, administrative controls,

11. Describe the genetic, physiologic, and psychosocial factors that affect susceptibility to adverse health outcomes following exposure to environmental hazards. 12. Explain approaches for assessing, preventing, and controlling environmental hazards that pose risks to human health and safety. 13. Critique scientific literature in occupational and environmental health to determine its relevance to advancing practice-based strategies that reduce threats from environmental and occupational hazards. 14. Propose engineering, educational, policy and enforcement strategies that reduce occupational and environmental health risks in populations. 15. Summarize the role of policy, regulation and enforcement to prevent, modify and remove environmental and occupational hazards and risks. **DrPH Competencies** 1. Synthesize information from multiple sources for epidemiologic research and practice. 2. Demonstrate basic ethical and legal principles pertaining to the collection, maintenance, use and dissemination of epidemiologic data. 3. Interpret epidemiologic data following scientific standards.	and personal protective controls. They should be familiar with the basic technical aspects of engineering controls and personal protective controls. Students will be familiar with a wide range of agricultural health disorders and understand the relationship between exposures and health effects. Students will understand the basic principles of occupational medicine, industrial hygiene, occupational health nursing, occupational safety, and ergonomics.

4. Weigh risks and benefits of public health screening programs. **PhD in Epidemiology-Biostatistics competencies** 1. Demonstrate the ability to review and critically evaluate the literature in a substantive area of research, be able to identify gaps in knowledge and be able to formulate original research hypotheses or statements. 2. Evaluate the strengths and limitations of epidemiologic reports. 3. Draw appropriate inferences from data. 4. Demonstrate an understanding of concepts of probability and statistical inference as they apply to problems in public health.	

. Understand the principles of epidemiologic study design and be able to calculate the appropriate epidemiologic measures for most typical designs. Demonstrate an understanding of research methods used in epidemiology and biostatistics.	

Textbooks and Other Materials

No textbook is required for this course. Course handouts, articles and lecture notes will be distributed via Canvas. Required readings from journal articles, manuscripts, and other documents are provided via Canvas. Students are responsible for securing their own copies of the readings and reviewing the materials prior to the class.

Evaluation

The course will consist of seminar/discussion classes, lectures, and self-study. The course will be enhanced by an online component in Canvas which will provide resources for accessing class materials including assignments and readings. Students will be required to complete five problem sets (50 points each; 250 points total); two field exercises associated with field trips to agricultural work sites (25 points each; 50 points total); and write a research paper on a question concerning a selected chronic disease (40 points) and provide a presentation on this topic for approximately 15 minutes (10 points). There will also be a mid-term (50 points) and final examination (100 points). Total points = 500.

Assignments and Tests	Points
Homework Problem Sets: 5 at 50 points each	250
Site Visit Exercises: 2 at 25 points each	50
Research Paper on Selected Safety and Health Topic	40
Oral or Video Presentation of Agricultural Safety and Health Topic	10
Mid-term Examination	50
Final Examination	100
TOTAL	500

Letter grades for the course will be assigned on a percentage basis (as given below) for the student's total score as a percentage of the total number of points possible for the course.

Grade	%	# Points
A	90-100	≥450
B	80-89	400 – 449
C	70-79	350 – 399
E	≤ 69	<350

Reading Discussion and Class Participation: **Students are required to participate in discussions on agricultural health and safety during class meetings. This requires that students are well prepared by having read the assigned literature and have completed homework assignments or other activities for generating discussion. A presentation of major issues, controversies, or basic information on a wide variety of agricultural health and safety topics will be presented to the class. However, most of the classroom time will be spent in interactive discussion with professor questioning and student answering.**

Problem Sets: **The problem set assignments involve literature research, evaluation of research findings, and applied computations relevant to agricultural health and safety topics. The assignments must be completed and handed in on the due date. Problem sets will generally be assigned such that students have approximately one week to complete them. The assignments must be the students' own work (i.e. each student must turn in a completed assignment), but students are encouraged and allowed to work together in solving the problems and assisting each other with the exercises. Two problem sets will also be concerned with hazards and control measures observed during site visits to working agricultural sites.**

Instructor Expectations

1. I expect you to be prepared to begin work at the scheduled starting time for
2. each session.
3. I expect you to actively participate in the discussions. This is not the type of class where you can "sit back and listen."
4. I expect you to submit papers using proper English grammar, syntax, and spelling. You are encouraged to use spell check and grammar check prior to submitting your written work. The Writing Laboratory is available to anyone who may need assistance. Grammar, syntax, and spelling will account for 10% of the grade for written work.
5. I expect (and encourage) you to provide honest and timely feedback regarding the content and process of this course throughout the semester.

6. I expect you to share in the responsibility for making this course an enjoyable and beneficial learning experience.

Academic Policies

It is the student's responsibility to be informed concerning all regulations and procedures required by the program of study, College or the University. Students should become familiar with the Undergraduate Bulletin or the Graduate School Bulletin as appropriate. Academic disputes will be evaluated against these policies. This serves as formal notification of academic policies.

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- Verification of Absences
- Student Resources

A hard copy of the policies will be provided by the Office of Academic Affairs upon request by the student.

Late Work Policy

Students are expected to take the examinations or turn in exams on the day scheduled in the syllabus. Students who cannot take the examination on the scheduled day must have an excused absence (illness of student or family member, death of family member, university sponsored trip, etc.) as defined in the *Student Rights and Responsibilities* handbook. Students should inform the faculty in advance of the examination if a problem exists with respect to taking the exam on the designated day. Students will be given the opportunity to make up missed work or exams in the event of excused absences. Students are entitled to excused absences for the purpose of observing their major religious holidays. If assignments are not turned in before they have returned to other students, the students will be penalized for turning in work late (2 to 8 points depending upon the degree of lateness).

It is at the discretion of the faculty member to assign an 'I' grade. The students will be given a 12-month period to complete the work for final completion and defense of the Capstone. If a student does not complete the Capstone within the 12-month time period, a grade of 'E' will be assigned.

Course Schedule and Topics

Class Schedule – Fall 2018

Class	Month	Date	Topic	Problem Sets Assigned
1	Aug	28	Agricultural Populations – Special Populations at Risk – Who is a Farmer? (Sanderson, Rice & Vincent)	
2	Sep	4	Infectious Diseases - Zoonoses including Zika (Winter)	
3	Sep	11	Agricultural Machinery and Transportation Hazards (Vincent)	#1
4	Sep	18	Traumatic and Musculoskeletal Injuries in Agriculture, Forestry, and Fishing – (Vincent)	
5	Sep	25	Dust and Gas Exposures (Sanderson)	
6	Oct	2	Exposure to Agricultural Chemicals (Sanderson)	#2
7	Oct	9	Respiratory Diseases (Sanderson)	
8	Oct	16	Cancer Risks for Agricultural Populations (Sanderson) **Mid-Term Examination**	
9	Oct	23	Exposure to Physical Agents – Heat Stress, Noise and Radiation (Sanderson)	#3
10	Oct	30	Skin Diseases / Personal Protective Equipment (Prince)	
11	Nov	6	Health and Safety Hazards on the Timber Industry (Stringer)	#4
12	Nov	13	Behavioral and Psychosocial Risks – Health and Safety Training (Mazur)	
13	Nov	20	Thanksgiving Break – No Class	
	Nov	27	Regulations and Health and Safety Management Programs (Vincent & Rice)	#5
14	Dec	4	Managing and Evaluating Programs; Emerging Issues in Agricultural Health and Safety (Rice)	
--	Dec	11	**Final Examination at regular class time period**	

The lecture schedule and due dates for the Problem Sets are subject to change depending on the schedules of faculty and the progress of the course. Students will be given notice in the event of a change in the schedule. The problem sets will be due before the

The dates and times for the field visits to agricultural work sites will be arranged during the semester.

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VITA

Olumuyiwa Moses Desmennu

Education institutions attended and degrees awarded.

University of Kentucky, Lexington, KY, USA; PhD, **2023**
University of Kentucky, Lexington, KY, USA; RMinE, **2020**
University of Ibadan, Nigeria; MEd. Evaluation, **2018**
University of Ibadan, Nigeria; MSc, Biochemistry, **2004**
University of Ilorin, Nigeria; BSc, Biochemistry, **1998**

Professional positions held.

University of Kentucky (2020 – 2023)

Academic roles

- Research and Teaching Assistant, Educational Policy studies & Evaluation (Jan – Aug 2023)
- Teaching Assistant, Chemistry Department (Jan – Dec 2022)
- Graduate Research Assistant, EPE Department (Aug – Dec. 2021)
- Teaching Assistant, Chemistry Department (Jan – May 2021)

Research roles

Graduate Research Assistant, Student & Academic Life (Feb – May 2020)

Service and support roles

- Student Officer, Student Parent Organization (May 2022 – May 2023)
- Coordinating Officer, Nigerian Graduate Student Association (Sep 2021 – May 2023)
- Institutional Affairs Officer, Graduate Student Congress (Sep 2021 – May 2022)
- Cultural Sensitivity Advocate, Graduate Student Congress (Mar 2020 – May 2021)
- Intern, Office of Strategic Planning & Institutional Effectiveness (May – Aug 2020)

University of Ibadan (2010 – 2019)

Academic roles

Junior Research Fellow, Institute of Education (Oct 2018 – Dec 2019)

Service and support roles

- Principal Executive Officer, Research Management Office (Oct 2016 – Sep 2018)
- Senior Executive Officer, Research Management Office (Dec 2012 – Sep 2016)
- Program Officer, Research Management Office (Jan 2010 – Dec 2012)

Scholastic and professional honors

- Academic Staff Training and Development Scholarship Awarded by the Tertiary Education Trust Fund, Abuja, Nigeria for Doctoral studies at the University of Kentucky, United States - 2019 – 2023
- Travel Grants to attend Second African Research University Alliance Conference, Nairobi, Kenya by the International Research Exchange Board (IREX), Washington DC, funded by the Carnegie Corporations, United States of America - 2019
- UASP Alumni Travel Grants to attend Annual Meetings of the Society for Research Administrators International at Hilton San Fransisco Hotel, United States by the International Research Exchange Board (IREX), Washington DC, funded by the Carnegie Corporations, United States of America - 2019
- Research Management and Leadership Fellowship of the International Research Exchange Board (IREX), Washington DC, funded by the Carnegie Corporations, United States of America, (Attachment was at the Office of the Vice President for Research, University of Kentucky between 23 Sept. and 3 November 2018) - 2018
- Travel Grants to attend 2018 International Network of Research Management Societies at Edinburgh International Conference Centre, Edinburgh by South African Research and Innovations Management Associations (SARIMA) and African Academy of Science (AAS) - 2018
- University Leadership and Management Training Program (UNILEAD), Carl von Ossietzky Universitat Oldenburg, Germany (Dec. 2016 – Sept. 2017) - 2016
- Travel Grant to visit Northwestern University Centre for Global Health on Grants and Contract Management by the Centre for Global Health, Northwestern University, Illinois, USA -2014

- Travel Grants to attend Sub-Saharan Africa Grant Writing and Peer Review Workshop by National Institute of Health at Thambo Hotels, Johannesburg, South Africa - 2013
- Development Research Uptake in Sub – Saharan Africa (DRUSSA) Short Course in Bibliography and Scientometrics in Stellenbosch University, Capetown, South Africa funded by the Association of Commonwealth Universities - 2013
- Development Research Uptake in Sub – Saharan Africa (DRUSSA) Short Course in Research Evaluation and Science Communication in University of Ghana funded by the Association of Commonwealth Universities - 2012

Conferences presentation

- Strategies to enhance the visibility of the student parent at the University of Kentucky, a paper presented at the 2023 National Student Parent Support Symposium, held at Blackwell Inn/Pfahl Conference Centre, Columbus, Ohio, USA, 10 – 12, May,2023
- Shifting your mindset for improved research management competencies, a paper presented at the 2023 iSeries conference of the Society for Research Administrators International, 23 – 25, April 2023.
- How to Engage Across Fields as a Research Manager, a paper presented at the 2022 iSeries conference of the Society for Research Administrators International, 19 – 22 May 2022.
- Investigating the influence of the United States Higher Education system on Higher Education systems in Nigeria, Egypt, and Afghanistan, a paper presented at the 65th Annual Meeting of the Comparative and International Education Society held virtually between 25 April – 2 May 2021.
- Harnessing capacity and working in power structures to develop an Electronic Research Administration (eRA) system, a paper presented at the Second African Research Universities Alliance (ARUA) Conference, held at the University of Nairobi, Kenya, 18-20 November 2019.
- When exactly does the Impact of an Intervention Program begin to wane? A paper accepted for presentation at the American Evaluation Association's (AEA) 33rd Annual Conference, Held at the Minneapolis Convention Center and the Hilton Minneapolis, United States, 11 – 16 November 2019.
- Development of the Electronic Research Administration system for the University of Ibadan (DeRA-UI): Lessons Learnt, a paper presented at

the Society for Research Administrators International Annual Meeting, held at the Hilton San Francisco Hotel, San Francisco, United States of America, 19 -23 October 2019.

- Data Management and Commercialization of Research among Early Career Researchers. A paper presented at the 12th WARIMA International Conference and Workshops held at the University of Ibadan, Ibadan, Nigeria, 25 – 29 November 2018.
- Effective Administration and Financial Management of Sponsored Research. A paper presented at the 12th WARIMA International Conference and Workshops held at the University of Ibadan, Ibadan, Nigeria, 25 – 29 November 2018.
- Access to Online Resources and Early Career Researchers' Web Footprints. A paper presented at the 12th WARIMA International Conference and Workshops held at the University of Ibadan, Ibadan, Nigeria, 25 – 29 November 2018.
- Research Management and Evaluation: a paradigm in Higher Education management in Sub- Saharan Africa: Paper accepted for poster presentation at the Evaluation 2018, a Conference of the American Evaluation Association, Cleveland, Ohio, 29 October – 3 November 2018.