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A New Course Development in Usability Engineering: Hands-On Learning Based on Research Work

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A NEW COURSE DEVELOPMENT IN USABILITY ENGINEERING: HANDS-ON LEARNING BASED ON RESEARCH WORK

Introduction

Usability is defined as the extent to which a system, product, or service can be used by specified users to achieve specific goals with effectiveness, efficiency, and satisfaction in a specified context of use [1]. The field of usability is known under names like Computer-Human Interaction (CHI) or Human-Computer Interaction (HCI) [2], and User Experience. Usability is also an area of knowledge that is interconnected with other concepts like Human Factors Engineering, Ergonomics, and Design Thinking. While some references use terms like Human Factors Engineering, Ergonomics, Usability Engineering (UE), or Human-Computer Interaction interchangeably [3], each of these concepts can be defined independently. Human Factors Engineering is a discipline that is not only useful for reducing errors and injuries but also aims to enhance and provide evidence-based practice for usability [4]. Design thinking begins with skills designers have learned over many decades in their quest to match human needs with available technical resources within the practical constraints of business [5]. Ergonomics is defined as the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data, and methods to design to optimize human well-being [6]. Therefore, knowledge drawn from these three areas complements Usability learning.

Several schools offer courses on User Experience or Human-Computer Interaction at both the undergraduate and graduate levels. Several platforms offer independent and self-paced online courses on HCI and User-Centered Design. Usability engineers come from different educational backgrounds and with different degrees like cognitive or organizational psychology, human factors engineering, computer science, and information science [7]. The Accreditation Board for Engineering and Technology (ABET) listed that the requirement for an Industrial Engineering curriculum is to prepare graduates to design, develop, implement and improve integrated systems that include people, materials, information, equipment, and energy [8]. While many Industrial Engineering curricula include courses on Ergonomics and Design, they do not necessarily cover concepts like Usability and User-Experience.

As industrial engineers are more involved in designing systems and tasks, it is beneficial for them to learn about UE and its application to these systems and tasks. While several textbooks on usability are available for example [2], [9], [10], and [11], the majority of these textbooks discussed the topic of usability from the standpoint of HCI. This view of usability comes short when considering the usability of an industrial system, task, equipment, or product that neither includes a display nor is operated by a software interface. Therefore, offering a course on UE to

Industrial and Biomedical Engineers required more resources to acquire knowledge on the concept and the application beyond what is available in textbooks.

Educational providers at all levels can and must do more to better prepare today's students for tomorrow's jobs [12]. Găbureanu [13] stated that employers not solely wish that employees possess discipline-specific competencies or technical skills, but also expect them to demonstrate competencies in a broad array of skills including critical thinking (CT). This is aligned with how universities and accreditation bodies call for CT in new graduates [14]. For example, ABET recommended embedding CT instruction along with other generic engineering competencies in engineering curricula [15]. This can be achieved by considering the characteristics of real problems and encompass problem-based learning strategies and environments [15]. Researchers identified two main pedagogical orientations on teaching CT; one stressing theory and the other focuses on practical knowledge and skills [13]. One view of developing CT is that it could be achieved by processing domain-specific knowledge [13], another view of CT considers it a skill that is characterized as a set of capacities, such as analysis, evaluation, interpretation, and puts a lot of emphasis on the importance of monitoring to evaluate the quality of thinking, and capacity for self-correction [15]. Student-led projects and problem-based learning are examples of assignments that promote CT [13]. Similarly, a research review assignment where students select a peer-reviewed research paper to either discuss in class or to critique in a written assignment is an example of an assignment that promotes CT skills.

This paper describes how a course on Usability Engineering was developed and delivered. The paper gives an elaborate description of the use of several assignments including research review to enhance students' learning and promote CT skills.

Course Description

A 3-credit graduate course at the 6000-level in Usability Engineering was delivered in Fall 2019 for the first time. The Course was offered by the Department of Industrial and Entrepreneurial Engineering and Engineering Management at Western Michigan University. Enrollment was open to students in the Industrial Engineering Master's Program and students in the Biomedical Engineering Master's Program. Course pre-requisites are Engineering Statistics or Design of Experiment (3 credits) and Ergonomics (3 credits). These courses could have been completed at the undergraduate or graduate level. Since this course was offered as an elective to both programs, only two students (one from each program) were enrolled in this first offering of the course. Due to the impact of COVID-19 pandemic on student enrollment, the course was not offered in Fall 2020.

Course objectives included: 1) Understand and prioritize usability problems, 2) Apply human factors principles and design thinking guidelines in the design, evaluation, and assessment of products, 3) Apply international standards and usability guidelines to products and systems to ensure usability requirements are met, 4) Conduct a formal process of usability evaluation using appropriate users as subjects/participants, 5) Analyze quantitative and qualitative usability

evaluation data and perform cost analyses for management, 6) Understand the ethical responsibilities and ramifications of collecting data on humans.

The syllabus shown in (Table 1) lists the topics that were covered during the semester. As discussed earlier, Usability as an area of knowledge overlaps with several other areas of knowledge, therefore it was essential for students to learn about Human Factors, understand Human Capabilities and Human error as well as being able to practice design thinking before being able to test the usability of systems or products. Topics covered were drawn from six textbooks and references which are listed in Appendix A, the instructor chose textbooks that are available in the University's e-library with full access to students.

Table 1: Course Syllabus

Week	Topic
Week 1	Introduction to Usability Engineering. Research Methods
Week 2	Understanding Human Capabilities
Week 3	Designing for the Human Being
Week 4	Design Thinking: Understanding Design Thinking
Week 5	Design Thinking: Tools for Design Thinking
Week 6	Usability Life cycle
Week 7	Usability Heuristics
Week 8	Usability Testing
Week 9	Usability assessment beyond testing
Week 10	Usability program
Week 11	Economic Value of Usability Testing
Week 12	Introducing Usability and design thinking into organizations

Course Structure

Davis [16] discussed several patterns to structure a course, the one followed in structuring this course is shown in (Table 2). The first step in the proposed structure discusses how ideas have evolved chronologically, this has been covered in week-1 where students learned about the history of usability, the key attributes of usability, and the international and industry-specific standards related to usability testing or designing a usable product.

The second step in the structure discusses how relationships occur in the real world, during weeks 1 through 5 several topics were discussed to build this step. During those weeks, students learned about several concepts drawn from Human Factor Engineering, Ergonomics, and Design Thinking. The objective was to build the needed knowledge drawn from these fields so that students can apply these concepts to usability and be able to identify how usability is interconnected to these fields.

The third step in the structure discusses how students will use the information in a career setting. This step covers the overarching goal of the course, which is to prepare students for their future job, therefore this step was incrementally covered throughout the semester. In week-1, the instructor discussed the common qualifications required in a usability engineer based on recent job posts. Requirements were explained to students and highlighted to show how they are in alignment with course objectives and outcomes. Starting from week-2 through week-12, students built incrementally the knowledge on how to conduct usability testing not only through lectures but also via the in-class research review discussions which will be detailed in the Assessment section below.

Steps four and six discuss how the major concepts and relationships are organized in the discipline and how knowledge is created. Topics covered throughout the semester incrementally provided the knowledge needed to cover these two steps. Starting with how usability is interconnected with other fields, then how to conduct usability testing, how to validate the economic value of usability testing, and finally how to introduce usability in an organization.

Table 2: Pattern for ordering topics

Step	Pattern for ordering topics	Usability Engineering Course Topics/ In-class discussions	Week
1	How ideas have evolved chronologically	Discussing the history and the importance of Usability	1
2	How relationships occur in the real world	Understanding how concepts like Human Factors, Ergonomics, and Design thinking are interconnected with Usability.	1-5
3	How students will use the information in career settings	Discussing the trends in the job market, learning about usability standards, and discussing research work on usability testing	1-12
4	How major concepts and relationships are organized in the discipline	Developing the connection between different disciplines and Usability. Understanding the different types of usability testing, being capable to apply the concepts in assignments and the course project	2-12
5	How students develop competencies from prerequisite to novice to expert skill sets	With instructions on research methods, usability testing, and in-class discussions on research reviews, students progressed to have expert skill sets.	1-12
6	How knowledge has been created in the field	In-class discussions on research reviews, critiquing research reviews to draw conclusions based on topics discussed in class and industry standards in usability	2-12

Step five discusses how students developed competencies from prerequisite to novice to expert skill sets. Again, this has been incrementally provided throughout the semester, starting from week-1 where students learned about research methods followed by the weekly in-class research review discussion. Students built upon the knowledge they already possess from previous courses on Ergonomics and Statistical Data Analysis (prerequisite).

Along with the lectures and research review assignments, students started to master the concepts of Usability Testing, relevant research methods, data analysis, the use of standards to build a test protocol, and finally conducting their course project where they applied their knowledge (expert).

Assessment

Students' performance was assessed by several assignments, a course project, quizzes, and exams. The grading scheme and assignments are shown in (Table 3).

Table 3: Assignments and Grades

Assignments	**Grade**
Reading assignment and discussion	20%
Weekly paper	10%
Usability Portfolio	5%
Lab activities & Homework	15%
Project	25%
Exams	25%

Homework and Lab activities were designed to directly assess students' understanding of topics covered in lectures. Four Homework assignments and lab activities were spread out throughout the semester.

The reading assignment was delivered weekly in class. Students were asked to select 2-3 research papers that were published in a peer-reviewed journal to discuss in class. In their presentation, students were asked to critique each research paper by discussing the following:

- Research problem, objective, and hypothesis.
- Methodology and data analysis.
- Critique (strength and weakness).
- Compare and contrast research papers.
- Key takeaways.

An open discussion lead by the instructor was conducted after the presentations. In the discussion, the instructor asked open-ended questions on the research methods, how they can be applied to other products or industries, what are the new concepts that were introduced, and how these new concepts tie back to course content.

By the end of the semester, more than 50 research papers on usability testing were discussed in the class. Topics covered several products drawn from different industries including surgical tools, surgical simulators, chair controls, display monitors, using virtual reality in usability testing, and more.

The weekly paper (self-reflection) was a weekly assignment in which students discussed the main key takeaways from the lecture and the in-class research review discussions. They also listed the main concepts that they will include in their usability portfolio.

Usability Portfolio was the last assignment that students completed by the end of the semester. Students were asked to build an e-portfolio to use as a resource when conducting future usability studies. In completing this assignment, students used information from lecture notes, textbooks, and in-class research review discussions to build their portfolios.

Course Project was a semester-long assignment in which students conducted a usability study on a product of their choice. Students developed a full usability testing plan, a detailed design of experiments, a research methodology, then they recruited human subjects to test the usability of their chosen product. Students presented their project to the class and submitted a written report to document their work.

Two exams were administered throughout the semester. Exam questions included multiple-choice, true or false, fill in the blanks, and short answer questions. Exam questions covered all the topics discussed in the classroom with a focus on how knowledge can be applied to testing the usability of certain products or systems.

Course Evaluation

Students enrolled in this course came from different majors, namely Industrial Engineering and Biomedical Engineering. Students participated in a survey to evaluate the course as well as their learning experience. When students were asked to rate how much did the course improve their understanding of concepts and principles in the field, 100% of the students answered that they strongly agree (rated 5 on a scale from 1 to 5 where 1 is “strongly disagree” and 5 is “strongly agree”). Students provided positive comments on their learning experience and emphasized on the benefits of the research review assignment in improving their understanding of the concept and principles of usability.

When students were asked to rate the usability portfolio as a resource to use in future tasks requiring knowledge on usability, 50 % of the students answered (4) while the other 50% answered (5) considering a scale from 1 to 5 where 1 is “strongly disagree” and 5 is “strongly agree”.

Research Review in STEM Education

An online survey was conducted to evaluate the effectiveness of research review assignments in STEM education. The survey was created on Google Forms and was distributed electronically on several online platforms soliciting participation from current or former students in STEM. Twenty-two STEM students participated in the survey, the distribution of their latest or current degree is shown in Figure 1.

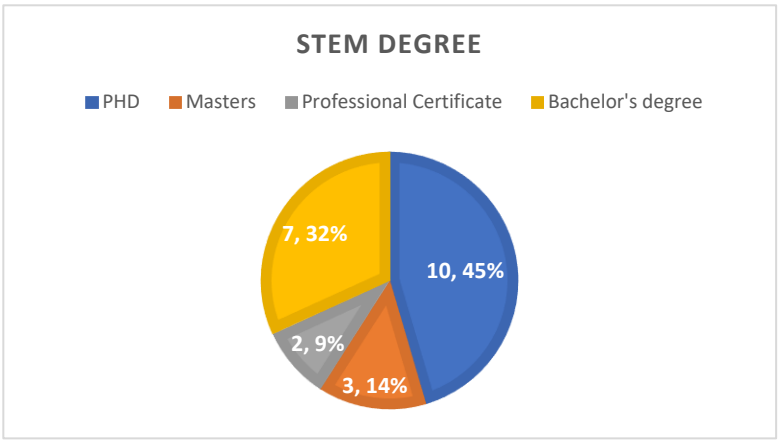

Figure 1: STEM Degree Distribution

When students were asked about the average number of research papers reviewed per course (see Figure 2), 41% of the survey participants read less than five research papers per course, 41% read more than 10 research papers per course and 16% of the participants read between 6-10 research papers.

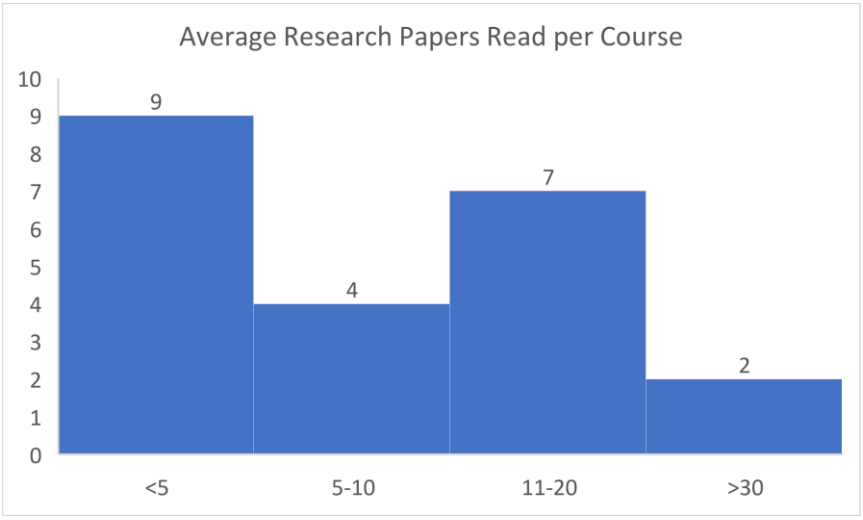

Figure 2: Average Research Papers Read per Course

Participants also listed whether they received any formal instructions on research methods and statistical data analysis (Figure 3), with 50% of the participants have received neither instructions on research methods nor statistical data analysis. As for the delivery method of the assignment, 68% of students indicated that research review assignments were either presented in class or discussed in class and 22% indicated that research review assignments were only submitted via a written report. Survey participants also rated their learning experience with research reviews on a scale from “1” to “5” where “1 is very poor “, and “5 is very good” (Figure 4).

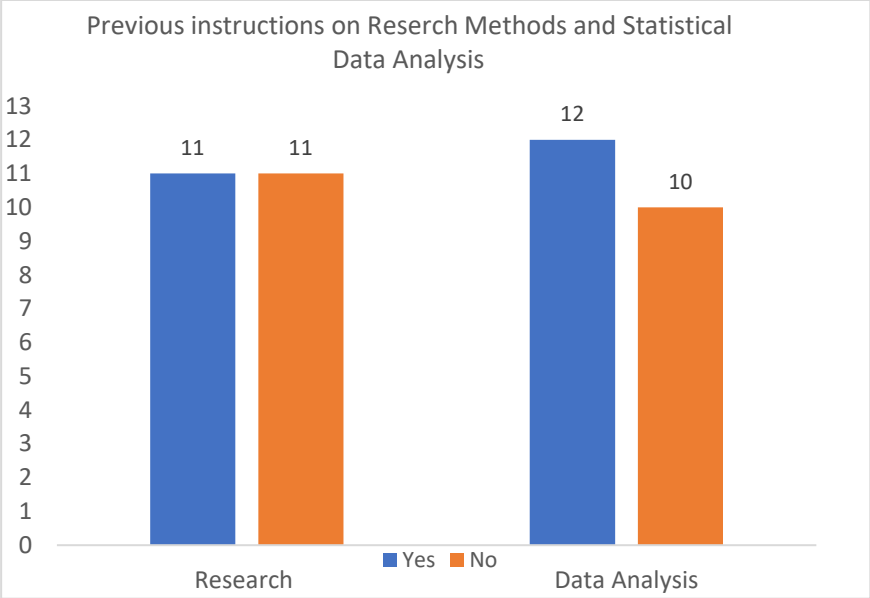

Figure 3: Instructions on Research Methods and Statistical Analysis

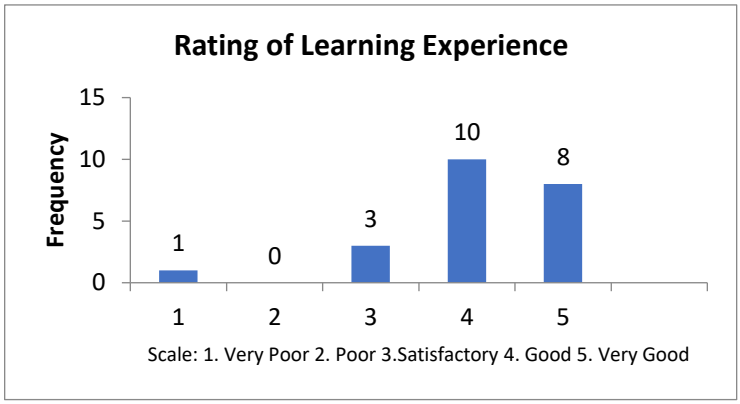

Figure 4: Rating of Learning Experience

The results of this survey indicated that the use of research review assignments is common in STEM education. It also points out that students could be assigned a research review assignment without receiving formal instructions on research methods and /or statistical data analysis. Survey results were further analyzed to investigate if receiving formal instructions on statistical analysis and research methods influence students' learning experience. The results showed that receiving formal instruction on research methods did not have a significant effect on students' learning experience. On the other hand, receiving formal instructions on statistical analysis was found significant (p-value < 0.05).

Conclusion

This paper discussed how a new course on Usability Engineering was structured, and how research review assignments were used to bridge the knowledge gap between textbooks, international standards, and real-life application of usability testing in various industries. Based on students' course evaluations, research review assignments were considered a main strength of the course. Research review assignments teach critical thinking skills and provide a window for students to experiment with how usability testing in the industry is conducted. Being able to critique, analyze and discuss how researchers conducted usability testing enhanced the students'

critical thinking skills. Other assignments like the weekly paper (reflections) and the usability portfolio were also highly rated by students.

Based on the experience of designing this course and the feedback provided by students, it is highly recommended that usability courses provide interweaving knowledge drawn from textbooks and research conducted on usability testing in the area of interest (i.e., product design, healthcare, mobile devices, written instructions, HCI, etc.). It is also recommended that research review assignments be discussed in the classroom rather than limiting the assignment to a written paper. It is highly encouraged to allow students to provide peer reviews on the presentations which will positively contribute to motivating students, enhancing their critical thinking skills, promote active learning, increase student engagement and strengthen the collaboration among students.

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