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Use of KEEN E-Module to Promote HF/E Creative Thinking in Biomedical Engineering Design Students

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***Abstract*—There is currently a disparity between certain components of HF/E education and the practical skills needed to successfully influence design ideas in industry. Most HF/E degree project requirements are purely analytical and systematic, leaving little room for creative thinking, which is a critical aspect of ergonomic design innovation and research. This investigation is inspired by a search for synergy between multimodal design capacities (e.g. anthropometry, anatomy, and material properties) and KEEN (Kern Entrepreneurial Engineering Network), a learning resource program designed to foster creative thinking in engineering.**

The KEEN Program's resource, *Integrated E-Learning Module: Thinking Creatively to Drive Innovation*, is available to students through the University's primary online course content site. Designed to help foster innovation in design, the module helps bring awareness to the processes that engineers typically go through to solve a problem. For this investigation, the *Integrated E-learning Module* was applied in a senior biomedical engineering design course. The course challenged a team of five students to design a pelvimetry model training tool to improve obstetric outcomes. We studied whether the e-module was effective in boosting students' creativity in the design process.

Our observations suggested that the e-module heightened the team's awareness of creative design thinking, however, overall, it failed to engage students. Students described the e-module material as dry and reported that it did not inspire creativity, innovation or excitement.

We concluded that the KEEN e-module was not sufficiently interactive to inspire creativity among these students. Student feedback suggested that adding interactive electronic devices to the module would help to inspire design creativity. Based on this feedback, the authors suggest implementing a modified KEEN e-module that uses advanced technology and/or immersive virtual reality (VR) to assess and enhance learner capabilities and inspire creativity.

The HR/E design challenge results, and a review of the related coursework materials, suggests that students will better understand difficult concepts when they are presented in a visual and interactive way versus a classic textual representation. This insight, integrated into the KEEN e-module to inspire creativity, could enhance the learning experiences of engineering design students, and could also inform future studies related to creativity and learning.

Keywords: design; creativity; golden section; senior design projects; human factors; ergonomics

I. INTRODUCTION

Novel designs require an integration of psychology, sociology, biomechanics, emerging health care needs and functional design to address differences in human capabilities and daily needs. Real life examples serve as an introductory guide for designers as they define individual population groups and then apply their knowledge to design spaces where people live, work and return to health. There is currently a disparity between certain components of HF/E education and the practical skills needed to successfully influence design ideas in industry. Most HF/E degree project requirements are purely analytical and systematic, leaving little room for creative problem solving. Since creative thinking is a key influence for ergonomic design innovation and research [2], it should be an integral part of the HF/E curriculum. The inspiration for this investigation comes from KEEN (Kern Entrepreneurial Engineering Network), a learning resource program designed to foster creative thinking in engineering. The Keen Program's resource, an e-module selectively available to students through the University's primary online course content site, was written to help foster innovation among engineering design students. The module focuses on bringing awareness to the processes that engineers typically follow to solve a problem that integrates previous and newfound knowledge.

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The Kern Family Foundation funded the KEEN-Integrated E-Learning Modules Project with the goal of helping to develop an entrepreneurial mindset among undergraduate engineering students. The e-learning module was incorporated into regular engineering courses, and its content was reinforced through contextual course activities. The module presented a series of short answer and multiple-choice tests to evaluate student engagement. It also encouraged students to implement certain module exercises on their own time.

The *Integrated the E-Learning Module: Thinking Creatively to Drive Innovation* was applied to a senior biomedical engineering design course in which a doctor from the school of medicine challenged a team of five students to design a pelvimetry model training tool to improve obstetric outcomes. Pelvimetry is the practice of measuring the dimensions of a woman's pelvis to determine the preferred method of childbirth: vaginal or cesarean section. For this practice, the pelvis is palpated through the vagina to feel for the bony landmarks associated with pelvic dimensions. The sequence and accuracy of hand placement are essential to the correct practice of pelvimetry.

Currently, medical educators lack a model that can simulate the most important aspects of pelvimetry so that students can experience and learn the practice. The senior design team was charged with creating a pelvimetry device that modeled a pelvis with realistic tissue and included sensors to detect and provide immediate feedback on performance accuracy. For this project, we implemented the KEEN e-module and studied its effectiveness in boosting students' creativity in the design process.

It should be noted that the students also explored the potential application of the "golden section" as it relates to workplace design and human body dimensions [6]. The golden section is a basic ecological pattern whereby certain mathematical harmonies exist in nature, and, in this case between diversely sized bone structures. They applied this knowledge of the golden section to the pelvimetry design model.

II. Data/Formulation/Methodology

The *KEEN E-Module: Thinking Creatively to Drive Innovation* was given to a focus group of five biomedical engineering seniors prior to beginning the design project. This e-module introduced the topic of creativity in engineering, with the expectation that it would drive innovation in alternative and optimal designs and prove useful for inspiring creativity in the design process.

The students were asked to complete the online module over the course of three weeks as a part of the regular design course before coming up with alternative designs. The KEEN e-module essentially consisted of about 50 slides, which included some thinking activities and information related to the creative thinking process. The e-module was graded as extra credit when it was completed during the allotted time frame.

The study examined student feedback to assess whether application of the e-module helped to stimulate design thinking and creativity. The senior students in the selected design class were asked to complete a brief survey on KEEN at the end of the course. Included below are the original comments from students on the KEEN e-module and its effect on conceptual design:

Our group was exposed to the KEEN e-module before coming up with alternative designs... Exposure to this creativity module made our team more aware of creative design thinking, but the module's activity itself did not have any major influence on our strategy. A few critiques we had on the KEEN module include:

1. The module was very wordy and quite dry. There was a lot of lecture-like material but not a lot of advice as to how to implement or examples of how these activities were to be used. We felt it was overall a bit hypocritical and counterintuitive to be describing creative processes in just words.

2. It should overall be more interactive and should require the physical presence of all members. We felt that a big part of creativity in this project relied on our ability to bounce ideas back and forth, so doing the module independently was not as helpful to our thought process.

3. Some of the brainstorming activities were helpful, and some of the examples of previous inventors were educational. However, these activities (such as Mind Mapping, and highlighting the heterogeneity of our thought processes) would have been performed regardless.

4. Our project may not have been the best example for creative design thinking. Because our model involves really accurate simulation of tissue and bony landmarks, we're actually limited in some areas because we must maintain a degree of realism and adhere to the pelvimetry process.

In summary, because we were told to be aware of our creative thinking process, we were, but the KEEN e-module did little to aid us in creative thinking or the engineering design process. This module could be improved extensively with more group activities, interactivity, videos, etc.

In addition to the survey, a rubric was used to assess student performance in the contextual activity. The rubric enabled students to elaborate on the content of slides, specifically addressing whether the flow and content of presented material aided in the design process, and whether students learned about design from the slides. Students were also required to complete a feedback form to describe their experiences in deploying the module. The form asked students to rate their satisfaction with the module with respect to their own engagement in the design process, and their experiences of teamwork.

The special *Rubric for Assessing E-learning Module Thinking Creatively to Drive Innovation* was provided by the

KEEN Foundation. The final students' report was selected as major outcome targeted via the assignment.

The module assessment outcomes were categorized into four aspects: 1). Articulated creative component of work, 2). Reflected on the source of creativity (nurture vs. nature), 3). Applied divergent-/convergent thinking process to converge on a solution, 4). Applied an idealization technique to generate solutions (Ask-Ask-Ask method, Fishbone Diagram or Mind Mapping method).

Proposed rating options were: 1- Poor: Shows little or no progress in achieving outcome. 2 - Below Average. 3 - Average. 4 - Above Average: Shows evidence of progress in achieving outcome that reflects a merely acceptable level of mastery. 5 - Outstanding: Shows evidence of progress in achieving outcomes that reflects superior mastery.

The assessment of each student's level of attainment of the module outcomes was evaluated by a graduate teaching assistant. Articulation of students' work creativity was assessed in range (4-5). Reflections on the creativity were in range (3-5). Applied thinking (divergent vs. convergent) was in range (4-5). Applied techniques to generate solutions were in range (3-5).

The assessment rubric was completed and results, along with the final students' report, were submitted to the KEEN Engineering Unleashed group located at the University of New Haven, CT. All personal identifiers from these documents were removed before submission.

III. Analysis

Overall, it was reported that exposure to the KEEN e-module made the design team more aware of creative design thinking. Through the content of the module, they came to better understand that design is a process of learning and creating. However, the module itself failed to fully engage students. Students described the module material as dry and reported that it did not inspire creativity, innovation or excitement. Because the material was presented in an unengaging way, students did not retain the information presented, and the module did not have any major influence on the design strategy.

In conclusion, the KEEN e-module was not a sufficiently interactive tool for the participating group of students. Students felt that creativity could be better inspired with the addition of an interactive art component. Thus, the authors suggest that a modified KEEN e-module with a set of art exercises tailored for the engineering design project could be more effective in inspiring creativity.

IV. Conclusions

In summary, the students who participated in the KEEN e-module reported that, at best, using the module helped increase their awareness of creative design thinking. However, the module did little to aid them in applying creative thinking to the engineering design process. Although important, the ideas presented through the module were not communicated in a compelling way, and, therefore, students were neither interested nor were they willing to incorporate the presented concepts into their design process. This lack of engagement meant that students did not retain the concepts as well as they should have.

Student feedback suggested that this module could be improved extensively with more group activities, interactivity, videos, etc. These suggested improvements are mainly motivated by the idea that student engagement, paired with a genuine interest in being creative, are the primary factors that should be considered in any effort that seeks to boost student creativity.

Since the theoretical foundation of the KEEN e-module was not sufficient for this project, we added the golden section design concept and explained it to students separately. We also added the task of making a physical model of the device with added force sensors. It should be noted that the golden section concept and the experimental part of the project significantly improved students' understanding of the device's training purpose.

The students' rendering and 3D model printing significantly influenced students' stamina and project enthusiasm (Fig. 1).

Fig. 1. Example of students' work Frontal view of 3D Printed Pelvis.

The HR/E design challenge and review of the related coursework materials suggest that difficult concepts can be made easier to understand by presenting them in a visual, interactive way, rather than by a classic textual representation. This insight, when combined with the KEEN e-module's revised vision for boosting creativity, could lead to a future experiment in which creativity and learning is driven by a series of interactive activities incorporated into educational material.

Our observations suggest that engineering design students' creativity could be enhanced by implementing a modified KEEN e-module and by adding an advanced electronic controlling system to the pelvimetric model training. Application of technologically advanced force sensors would enable users of the model to observe the magnitude of applied force pressure at the defined bony marks. The biofeedback of applied force during the pelvimetric exercises would raise awareness of applied force during palpation by a trained person.

A second possible modification could be the use of virtual reality (VR) environments to assess and enhance learner capabilities in an immersive experience. However, the use of VR tools (headsets with interactive computer software) should be carefully monitored by an accompanying person because prolonged application of VR can result in user discomfort and disturbed balance during training.

Use of a biofeedback system and virtual reality in the device design process could give designers the opportunity to directly interact with their device in a simulated real-world environment.

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