Work-In-Progress: Effects of co-curricular activities on student learning outcomes related to an artificial intelligence, modeling, and simulations (AIMS) certificate program

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Abstract:
Current research documents the notable advantages active learning methods like project-based learning (PBL) and hands-on exploration have on student learning across a variety of disciplines including engineering. Recently, the Mechanical Engineering Department at The University of Iowa introduced undergraduate and graduate certificate programs in artificial intelligence, modeling, and simulations (AIMS) that aim to teach students: (1) the importance of uncertainty quantification, (2) the various types of combinations (e.g., modeling and simulation-assisted machine learning) and hybrid approaches, and (3) using hybrid models toward the design of intelligent complex machines. This work-in-progress seeks to understand how extra/co-curricular activities, as an extension of semester course content, can benefit student learning outcomes in courses related to the AIMS certificate programs. Project-based activities such as AIMS-related workshops offered by the university will be assessed to measure learning outcomes associated with engineering self-efficacy, judgment, and leadership skills.

Engineering self-efficacy (ESE) is an individual's belief in their capability to act in the ways necessary to reach specific goals. Judgment about one's abilities can influence behavior and goal attainment. We hypothesize that the groups' self-guidance during the hackathon will improve their ESE related to applying AIMS concepts. Next, engineering judgment (EJ) is an individual's ability to make and justify decisions and predict the resulting consequences. EJ is developed in parallel with engineering science calculations and design considerations. We hypothesize that the process of reflection and iteration inherent to hackathon competitions will strengthen the participant groups' perceived EJ skills. Finally, engineering leadership (EL) skills relate to the leadership style(s) used by individuals to lead groups of engineers to achieve a common goal. An effective leader exercises influence at interpersonal, team, and organizational levels, while simultaneously building strong relationships. We hypothesize that in the absence of a well-structured project, the need to delegate tasks among team members and develop solutions quickly will increase the perceived EL abilities of participant groups.

To frame this study, we will use the Buck Institute of Education's (BIE) Gold Standard PBL framework. BIE describes PBL as having three parts: Student Learning Goals, 7 Essential Project Design Elements, and Project-Based Teaching Practices. Our study focuses on student learning goals and three of the seven essential project design elements: student voice and choice, reflection, and critique and revision. This paper will present results from post-event surveys, while future work will focus on data obtained from semi-structured interviews. All data will be analyzed to extract themes relating to the students' perceived changes in self-efficacy, engineering judgment, and leadership ability as a result of participation in the hackathon.

Introduction:

Advancements in science, technology, engineering, and mathematics (STEM) have ushered in a new Information Age in which huge amounts of data are more accessible now than at any other time in human history. Analyzing and utilizing that data that has become an increasingly important and difficult task that often requires highly specialized domain knowledge. As a result, artificial intelligence (AI), an algorithm-based technology that mimics human intelligence to solve complex problems, has recently started to take hold in various

STEM-based industries. AI is generally regarded as consisting of two main subfields: machine learning and deep learning. Machine learning employs statistical methods to learn models or algorithms from data without explicit programming, while deep learning is a subset of machine learning that uses multi-layered neural networks to perform learning. Unlike AI, knowledge-based modeling, and simulation (M&S) techniques use models to generate data. Datasets and models generated from data have some uncertainty associated with them, making the analysis and design of complex products and systems exceedingly difficult. The Mechanical Engineering Department at a large public research-intensive Midwestern University has partnered with the U.S. Department of Education to create graduate and undergraduate certificates in artificial intelligence, modeling, and simulations (AIMS) to bridge the knowledge gap between AI and M&S approaches in conjunction with model and data uncertainty quantification.

The goal of this research is to investigate the effects of participation in co-curricular activities, as an extension of AIMS course content, on engineering self-efficacy (ESE), engineering judgment (EJ), and engineering leadership (EL) skills. To investigate these effects, students' experiences in participating in a 48-hour hackathon and AIMS-related workshops will be examined to assess student outcomes associated with engineering self-efficacy, judgment, and leadership skills. Major League Hacking, a B-Corp organization that partners with collegiate hackathons to provide organizers with resources and advice, describes hackathons as an "invention marathon," where people interested in technology can "learn, build and share," their creations with others [1]. The typical hackathon is structured around teams of four hackathon participants having 24 to 48 hours to create some sort of "demo-able" computer science-based project [1]. Intensive courses and team-based rapid development methods teach students to cooperate in groups and to help one another achieve their learning goals by collaborating. These methods have been proven to work in tertiary education in both domestic and international studies [2]. The challenges of solving an open-ended problem through self-guidance, intrinsic motivation, sustained inquiry, and critique/revision presented by a hackathon are predicted to relate to self-reported improvements in engineering self-efficacy, engineering judgment, and leadership ability of student groups who successfully participate in the hackathon [1-4]. At its core, cooperative learning, provided by co-curricular activities, is based on the premise that cooperation is more effective than competition among students for producing positive learning outcomes [5].

Self-efficacy is an integral element of motivational belief systems and influences students' academic behaviors and choices, such as mastery goal orientation, task value, and interest [3]. Importantly, students who believe in their capabilities also tend to engage in their work for their mastery and find their work useful and interesting [6]. Next, engineering judgment (EJ) is exercised throughout a design process and is what allows engineers to identify the key elements required for an analytical or experimental model. Eugene Ferguson, the author of *Engineering and the Mind's Eye*, implies that EJ is something informed by mathematics and science, but states that it is not reducible to them [7, 8]. EJ is developed through hands-on training and experience. Those who have developed sound EJ are often able to decide when mathematically "proven" results need to be overridden and when a calculation or estimation is precise enough. Finally, anecdotal evidence indicates that deferred EL development often puts the engineer at a disadvantage compared to other graduating majors where leadership is emphasized [9]. The legitimacy of the field depends on engineers recognizing themselves as members of a leadership profession [10].

The importance of engineering self-efficacy (ESE) is evident in the way it influences choices and motivation. Students with higher ESE tend to perform better, engage more with their work, and enjoy what they do more than those with low ESE [6]. Students with sound EJ are viewed by their peers and prospective employers as being more competent [4]. One who otherwise knows what engineers know but lacks ‘‘engineering judgment’’ may be an expert of sorts, a handy resource much like a reference book or database but cannot be a competent engineer [11]. An effective leader can exercise influence at interpersonal, team, and organizational levels, while simultaneously building strong relationships. A person with strong ESE, EJ, and EL skills has the potential to drive innovation and change in the fields of artificial intelligence, modeling, and simulation.

This work-in-progress paper aims to present a preliminary investigation into the relationships between the three aforementioned student outcomes, student interest in the AIMS certificates, and student participation in co-curricular activities (i.e., hackathon and/or AIMS-related workshops). This paper opens with a description of the framework undergirding this work, a description of the survey, participants, and setting, and a description of the analyses conducted on the data. Then, preliminary results are presented and discussed, followed by initial conclusions and future work.

Framework:

The Buck Institute of Education (BIE) describes project-based learning (PBL) as having three components: Student Learning Goals, Essential Project Design Elements, and Project-based Teaching practices [12]. At the core of the BIE PBL framework are the student learning goals, which include key knowledge, understanding, and success skills. Surrounding these core learning goals are the seven essential project design elements: 1) a challenging problem or question, 2) sustained inquiry, 3) authenticity, 4) student voice and choice, 5) reflection, 6) critique and revision, and 7) public product. Project-based teaching practices consist of 7 elements: 1) design and plan, 2) align to standards, 3) build the culture, 4) manage activities, 5) scaffold student learning, 6) assess student learning, and 7) engage/coach. This research-informed PBL framework was chosen for its adaptability and prioritization of learning goals, skill-building, problem-solving, and collaboration.

For this study, we will prioritize three of the seven essential project design elements to conduct our analysis: student voice and choice, reflection, and critique and revision. These elements most accurately reflect the process of developing engineering self-efficacy (ESE), engineering judgement (EJ), and engineering leadership (EL). In the context of PBL, student voice, and choice may involve assigning qualitative factors and applicable conditions for selecting formulas, discretizing (grouping elements to reduce the number of types to be designed), and making assumptions or simplifications to be the bases of mathematical models [4] [12]. As students enter the process of reflection, they may have to determine what is a good or precise enough calculation or estimation and determine which elements are typical for the problem. The iterative process of critique and revision may involve students overriding mathematically "proven" results and determining appropriate uses of technology tools.

Methods:

The goal of this research is to conduct a preliminary investigation into the effects of participation in co-curricular activities, as an extension of AIMS course content, on student outcomes. Survey data was collected from students enrolled in 5 AIMS courses during the last week of classes. A total of 57 responses were recorded from 14 graduate students and 43 undergraduate students. Likert-type items were used to indicate the level of agreement with questions related to perceived ESE [13], EJ [4], and EL ability [10] as shown below.

Table 1: Likert scale responses indicating the of level of agreement with perceived ESE, EJ, and EL ability

Strongly Disagree (1)
Disagree (2)
Somewhat Disagree (3)
Somewhat Agree (4)
Agree (5)
Strongly Agree (6)

Student interest in the AIMS certificates is categorized by the following options:

Table 2: Likert-scale responses indicating the level of interest in the AIMS certificate program

No, I'm not interested in applying to AIMS (1)
I'm not familiar with the AIMS program and I would not like to learn about AIMS (2)
I'm not familiar with the AIMS program and would like to learn about AIMS (3)
Yes, I'm interested in applying to AIMS (4)
I have already applied to AIMS (5)

Finally, students self-reported their participation in the hackathon and/or AIMS-related workshops. Responses for each of the aforementioned learning outcomes were grouped and averaged based on AIMS interest and workshop participation.

Results and Discussion:

The initial key focus of our analysis was the experience of mechanical engineering students enrolled in AIMS courses who participated in a 48-hour hackathon. Unfortunately, we were unable to collect data from students who met these criteria. Instead, the results section will present the relationships between engineering self-efficacy (ESE), engineering judgement (EJ), and engineering leadership (EL), followed by results describing the relationships between each of these constructs (ESE, EJ, and EL), student interest in the AIMS certificates, and student participation in AIMS-related workshops.

Results for the overall average and Pearson correlation coefficient for each construct (EJ, EL, and ESE) are found in Tables 1 and 2 below. The strongest relationship A strong relationship was discovered between EJ and EL, evidenced by a Pearson correlation coefficient of 0.744. A much weaker relationship was found to exist between EL and ESE with a correlation coefficient of 0.287. Lastly, EJ and ESE had a moderately strong correlation coefficient of 0.453.

Table 3: Average ESE, EJ, and EL scores for all students

Construct	Overall Avg.
ESE	5.34
EJ	4.68
EL	4.49

Table 4: Correlation Coefficient for ESE, EJ, and EL

Construct	Correlation Coeff.
EL-EJ	0.744
EL-ESE	0.287
ESE-EJ	0.453

Students were grouped into 5 levels of AIMS interest based on their survey responses. There were a total of 21 students with no interest in the program (group 1), 2 students with familiarity and no interest in learning more (group 2), 10 students who wanted to know more about the program (group 3), 14 students interested in applying to AIMS (group 4) and 8 students who already applied to AIMS (group 5). Groups 1 and 2 were combined and categorized as "not interested," while groups 3-5 were categorized as "interested". Figure 1 below shows the averages of the grouped responses while Figure 2 shows learning outcomes grouped by students' participation in AIMS-related workshops.

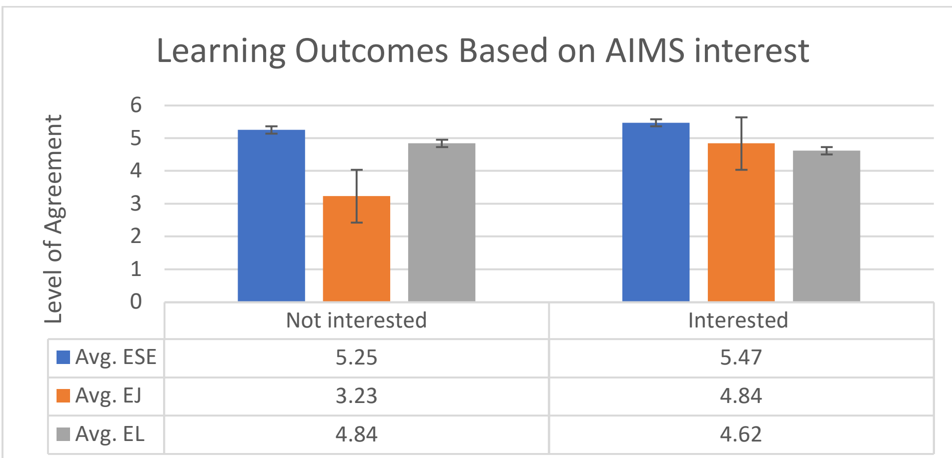

Figure 1: Learning Outcomes Based on AIMS Interest

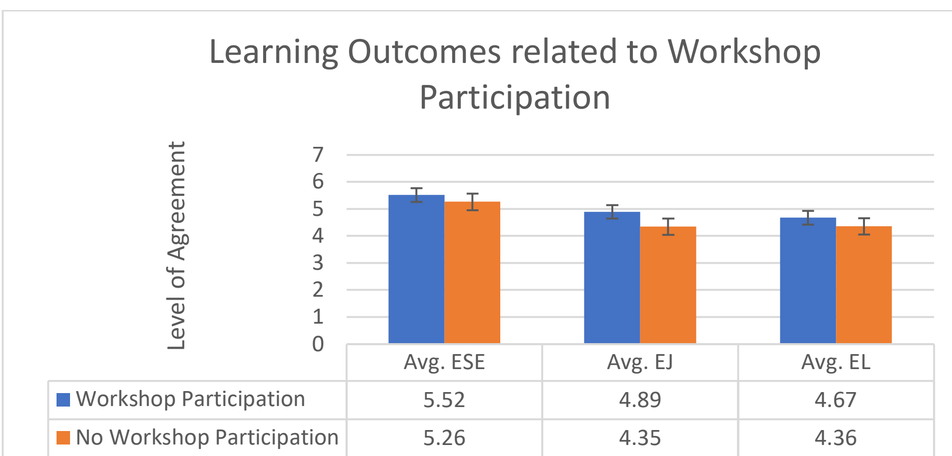

Figure 2: Leaning Outcomes Based on Workshop Participation

Discussion:

The preliminary data suggests that students who expressed any level of interest in the AIMS program self-reported the highest perceived levels of ESE and EJ, while students who participated in AIMS-related workshops showed the highest scores across all three categories. As such, students who engaged in activities beyond the core course requirements exhibit a stronger belief in their abilities as an engineer. However, there is a distinct possibility that the types of students who have higher levels of ESE are more likely to seek out additional professional development activities.

Conclusions and future work:

Current research documents notable advantages that active learning methods like project-based learning (PBL) and hands-on exploration have on student learning across a variety of disciplines including engineering. A new certificate program at a Midwestern University in artificial intelligence, modeling, and simulations (AIMS) aims to teach students: (1) the importance of uncertainty quantification, (2) the various types of and hybrid approaches, and (3) using hybrid models to design intelligent, complex machines. The goal of this research was to investigate the effects of participation in co-curricular activities, as an extension of AIMS course content, on student outcomes related to engineering self-efficacy (ESE), engineering judgement (EJ), and engineering leadership ability (EL). Due to a lack of data on our activity of interest, a 48-hour hackathon, data related to students' self-reported ESE, EJ, and EL was grouped according to the level of interest in AIMS and by participation in AIMS-related workshops and presented in the results section. Results show that students who participated in workshops exhibited higher average values across all three categories, while students who enrolled in or demonstrated interest in AIMS displayed the highest values for ESE and EJ.

Future work will focus on gathering more data on student participation in co-curricular activities related to AIMS, and interest in the program. Ideally, we will gather data from students who participate in next year's hackathon and follow up on their experiences by conducting semi-structured interviews to gain more insight.

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