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The Effect of Course Type on Engineering Undergraduates' Situational Motivation and Curiosity

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Abstract

This exploratory study investigated situational intrinsic and two types of extrinsic motivation, amotivation, and curiosity and how they were differentially impacted by 62 engineering undergraduates' participation in an IDEAS studio course and a comparison course (designated Course X). All IDEAS studio courses are small with an interdisciplinary mix of students. Students voluntarily register for these courses that include the creation of a physical artifact, a real problem and broad perspectives in class work, and an open process to create solutions. Participants in an IDEAS course were asked to select a comparison course that was the least like the IDEAS course. Three times throughout the semester situational motivation and curiosity were assessed for both courses using 21 questions selected from existing instruments. Results showed that at each of the three times during the semester when students completed the assessment, there was a significant difference between their situational motivation and curiosity for the IDEAS course and Course X. When evaluating the IDEAS course, students consistently had higher scores in intrinsic motivation, identified regulation and curiosity than Course X with large effect sizes. When considering Course X, they consistently had higher scores in external regulation and amotivation than the IDEAS course with large effect sizes.

Introduction and Background

As we move forward in the twenty-first century, there is a need for individuals who can see new possibilities, are curious about problems that arise, and dare to risk failure to solve those challenges with innovative solutions[(8)]. Engineering is one discipline where there has been a call for innovation, fueled by the entrepreneurial spirit[(16)]. Some have even proposed that innovation is the key to the "entrepreneurial mindset" [(10)]. However, innovative thinking and the "entrepreneurial mindset" are not automatic outgrowths of current engineering programs. What fuels innovative solutions? What makes one person risk embarking on a new endeavor while another does not?

Self-Determination Theory [(7)] can provide some insights. Self-Determination Theory involves the perception of options, a sense of considering oneself free to do what one has decided to do. It incorporates a continuum of levels of motivation which include intrinsic motivation, multiple types of extrinsic motivation, and amotivation[(12)]. When individuals are intrinsically motivated, behaviors are influenced by internal reasons such as personal enjoyment [(3)]. By contrast, when extrinsically motivated, individuals are influenced by external factors, such as a grade or a paycheck[(3)]. Amotivation is when individuals are neither intrinsically nor extrinsically motivated. As noted by Guay et al., amotivated individuals have, "…no sense of purpose and no expectations of reward or possibility of changing the course of events" (p. 177) [(12)].

Each level of motivation is correlated with different results [12]. Intrinsic motivation is associated with more positive learning outcomes, such as higher academic achievement [3, 7, 15] and is believed to be key for an "entrepreneurial mindset" in engineering students [11, 14]. By contrast, amotivation is associated with the most negative effects [12].

Since intrinsic motivation is related to positive learning outcomes and an "entrepreneurial mindset" [11], its promotion in undergraduate classrooms is important and should naturally result in its increase. However, a complex relationship exists between the encouragement of intrinsic motivation and that outcome. Cognitive Evaluation Theory, a sub-theory within Self-Determination Theory [7] provides some clarification. This theory, developed in order to identify variables that could clarify differences in intrinsic motivation, explains intrinsic motivation through individuals' needs for competence and autonomy [18], both identified as crucial for educational attainment and a sense of well-being [15]. Competence has been explained as, "…the need to experience satisfaction in exercising and extending one's capabilities" (p. 68) [15]. By itself, competence does not enhance intrinsic motivation; a feeling of autonomy has to go with it [18]. Autonomy has been described as a being able to make choices and to do things for individual rather than external reasons [15]. Ryan and Deci [18] further described autonomy as, "…the feeling of volition that can accompany any act, whether dependent or independent, collectivist or individualist" (p. 74).

Students who have more of their need for autonomy fulfilled seem to have a stronger performance and more intrinsic motivation than those who do not [18]. A need for autonomy has also been identified as necessary for productive entrepreneurs. "Entrepreneurs desire the ability to resolve their problems and to bring activities to a successful end on their own" (p. 257) [8]. Therefore, educational environments need to be developed that satisfy students' needs for autonomy as well as competence [2].

While some believe that extrinsic motivation excludes autonomy, Organismic Integration Theory (OIT), another sub-theory within Self-Determination Theory, hypothesizes that there can be varying amounts of autonomy within extrinsic motivation [7]. Ryan and Deci illustrated a range of levels of extrinsic motivation extending from external regulation through introjected regulation and identified regulation to integrated regulation. Each style varies by controllability and pertinent regulatory procedures [18]. Within the extrinsic motivation continuum, external regulation refers to behaviors that have the least autonomy. Behaviors are, "regulated by rewards or in order to avoid negative consequences" (p. 177) [12]. Individuals with high external regulation believe that the causality of outcomes is external [18]. This type of extrinsic motivation was frequently compared with intrinsic motivation in early research [18]. While introjected regulation is considered closer to external regulation, with identified regulation, individuals are starting to believe the causality of outcomes is slightly internal [18]. Integrated regulation, the closest to intrinsic motivation and therefore a highly self-directed type of extrinsic motivation [18], refers to appreciating a goal or activity as important but still being motivated by external reasons. In an educational setting, students high in integrated regulation would select and value courses related to their major but view them as a means to achieve a degree in a specific discipline or to acquire a particular job.

In addition to a sense of autonomy and competence, students need to be interested in course content and the problems they are trying to solve. Interest is another factor believed to facilitate learning [(13, 17)]. It has been broadly viewed as a mental state that arises from an individual's transactions with an activity [(4, 17)]. However, educational researchers have further categorized interest into personal and situational [(17)]. Personal interest is an individual's internal inclination for an activity or action [(4)]. Situational interest is the interaction between features of an activity and the person's perceptions of the activity or action [(4)]. Deci connected intrinsic motivation to situational interest, proposing that it is a multi-dimensional concept [(6)]. Deci argued that situational interest can be viewed as a trio of interactive groupings involving the individual and the activity: characteristics of the activity, mental inclinations of the person, and the interaction between the activity and how it is viewed [(4, 6)]. It is known that external influences such as competition, deadlines and restrictions can impact a person's situational motivation for a specific activity [(12)]; all are factors to consider in educational environments.

Hidi and Renninger proposed a four-phase model of interest development that suggested a dynamic relationship between curiosity and interest [(13)]. If curiosity is satisfied, then interest and engagement can occur. Furthermore, curiosity has been associated with a need for competence in Deci's theory of intrinsic motivation [(5)]. As Arnone, Small, Chauncey, and McKenna noted, "When curiosity is ignited, the interest component can then enter into the dynamic" (p. 188) [(1)]. Alternatively, interest can reactivate curiosity [(13)]. "It is the curious child that becomes tomorrow's innovator…" (p. 195) [(1)].

Intrinsic and extrinsic motivation, as articulated by Self-Determination Theory[(7)], as well as situational interest and curiosity may play important roles in promoting both learning and innovation, ultimately facilitating an "entrepreneurial mindset"[(16)]. However, there is a need for comparison environments to explore whether certain settings or classes are better at promoting these precursors of the entrepreneurial spirit. Researchers have indicated that motivation can vary for individuals when they are involved in an activity. This situational motivation has been has referred to by Vallerand as the "here-and-now" of motivation [(20)]. Previous research has also noted a need for comparable situations with analogous activities with high and low interest so they can be distinguished [(4)]. Investigations of motivation and interest need to occur in varied courses or classroom settings to provide further insights.

Purpose of the Study

The purpose of this exploratory research was to investigate how intrinsic and extrinsic motivation, as articulated by Self-Determination Theory[(7)], and curiosity were differentially impacted by engineering undergraduates' participation in two contrasting courses, an IDEAS studio course and a self-selected comparison course (designated as Course X). For the purposes of this study, amotivation, two measures of extrinsic motivation, intrinsic motivation, and curiosity (operationalized as situational interest) were examined. These variables were measured by the Situational Motivation Scale (12) and five questions from the Situational Interest Scale (4).

The IDEAS studio course was a university-specific class designed to encourage an entrepreneurial mindset and Course X was a course selected by students, which they believed was very different from their IDEAS course. Based on previous research (15), it was hypothesized that due to greater satisfaction of the need for autonomy when in the IDEAS course, students would have higher intrinsic motivation and identified regulation than in Course X, while they would have higher external regulation and amotivation in Course X than in the IDEAS course. It was also hypothesized that solving "real world" problems without pre-determined solutions in the IDEAS course would increase feelings of competence which would lead to greater curiosity (5) than in Course X.

Methods

A one-group pre-test-post-test design was used to investigate amotivation, extrinsic and intrinsic motivation, and curiosity to see whether they were differentially impacted by engineering undergraduates' participation in an IDEAS studio course and a student-selected comparison course, designated as Course X. IDEAS studio courses are two-credit-hour engineering electives designed to foster an entrepreneurial mindset. They often include close communication with industrial partners and a focus on issues like value, opportunity recognition, innovation, and customer engagement. All of the IDEAS courses were designed to promote seven core attributes:

- Each IDEAS course is voluntary; students elect to take the course and the course itself acts as a free elective.
- In IDEAS courses, most students make a physical artifact.
- The work students do in IDEAS courses is motivated by real-life problems. Many times the problems are supplied or inspired by industrial sponsors.
- Students apply broad perspectives to their work in the IDEAS course. Besides the technical viability of their ideas, students must explore the social impact, value, market viability, and other aspects.
- Students are encouraged to apply an open process to generate solutions in the IDEAS course. In many cases, students explore the process as an outcome for the course; they are told that neither the resulting solutions nor the process to reach them are pre-determined.
- IDEAS courses are open to all disciplines in engineering, and in some cases, to all majors throughout the University, resulting in an inter-disciplinary mix of students.
- IDEAS studios courses are small, and in most instances, the enrollment is limited to 16 students.

These courses also had the characteristics of an autonomy supportive environment as described by Levesque et al [15]. Students chose to take the IDEAS course as an elective, were encouraged to generate solutions to real-life problems where solutions were not pre-determined thereby giving them a situation where their viewpoints were valued.

Course X was independently and anonymously chosen by each student. It was to be a course in which they were concurrently registered and that, from their viewpoint, shared as few of the IDEAS course qualities as possible. Students were asked to select their own comparison course for a number of reasons. The main one was that students enrolled in the IDEAS course were from a variety of majors and therefore had no one other course in which they were all enrolled, preventing a direct comparison of courses. In addition, because the students' perceptions of the courses might be different from faculty intent, it was felt the students themselves would be the best judge of which other course was most different from their IDEAS course.

The Situational Motivation Scale [12] was used to measure motivation and amotivation. This is a multidimensional, validated instrument with 16 questions, designed to measure four kinds of motivation hypothesized by self-determination theory[7]: intrinsic motivation, two measures of extrinsic motivation (identified regulation and external regulation), and amotivation. Four Likert-style questions are used to measure each type of motivation with a range from Strongly Agree (5) to Strongly Disagree (1). A score is obtained by summing the responses to individual questions for each type of motivation.

While there has been an absence of agreement on an appropriate definition for curiosity [1], it is clear that curiosity, interest, and engagement are dynamically related. Therefore, curiosity was measured by taking five questions from an existing Situational Interest Scale [4]. Four of the questions came from the Exploration Intention factor and one from Instant Enjoyment. At the end of the course, students were surveyed about their perception of the seven course attributes listed previously in both their IDEAS course and Course X.

Paired samples t-tests were completed after each of the three times the assessment was administered to determine if there were significant differences in motivation and curiosity between the IDEAS course and Course X. Differences between the first and the final time the assessment was given were also determined. Cohen's d was used to measure effect size. Effect size measures "the magnitude of the treatment" (p. 207) [19]. The larger the effect size, the more meaningful the difference is between the means of the two groups. According to Fraenkel, Wallen, and Hyun, any effect size of .50 or larger [for Cohen's d], "is an important finding" (p. 248) [9].

A sample of convenience from one university was used. There were 62 engineering undergraduates across two semesters. The majority were White (66.7%) seniors (58.8%) with self-reported GPAs of 3.01-3.50 (51%). There were 40 males and 11 females. Students were from multiple engineering majors but the largest group was mechanical engineering (33.3%). Three times throughout the semester situational motivation and curiosity were assessed for both courses using 21 questions selected from the existing instruments previously noted. Students were asked to respond to the questions from the perspective of the class they were in (either the IDEAS course or Course X). The assessments were conducted online in the 2nd, ~6th, and final weeks of the semester. The evaluations asked students to consider their feelings about the most recent course meeting of their IDEAS course and of Course X as they responded to the questions. The results should therefore reflect students' motivational and curiosity state on three distinct days in the beginning, middle and ending of the semester. In addition, a questionnaire at the end of the semester asked students to reflect on the extent to which, in their view, the seven attributes of IDEAS courses were or were not present in both their IDEAS course and Course X. Students were offered a small financial incentive to complete the surveys. All identifiers were removed before analysis. Instructors did not have access to survey results during the semester, and were not involved in the assessment collection process.

Results and Discussion

While there was a total of 62 engineering undergraduates in the study, varying numbers of students completed the assessment at each administration time. The least number of students completed the evaluation the second time it was given, approximately in the sixth week of the semester. This is a limitation of the current study.

Descriptive Statistics for three different administrations of the assessment showed a pattern where mean scores for the IDEAS Course for intrinsic motivation, identified regulation and curiosity were higher than for Course X. Conversely, the mean scores for external regulation and amotivation were higher for Course X than the IDEAS Course. The differences followed the hypothesized pattern. When significance testing was done, all differences were found to be significant with large effect sizes.

Table 1: Mean Scores for the Three Administrations of the Assessment

	Mean Score for First Assessment n = 48	Mean Score for Second Assessment n = 38 IDEAS Course; n = 37 Course X	Mean Score for Third Assessment n = 54
Intrinsic Motivation IDEAS course	17.44 (SD = 2.03)	16.74 (SD = 1.83)	17.17 (SD = 1.85)

Intrinsic Motivation Course X	12.71 (SD = 3.67)	12.87 (SD = 3.25)	14.22 (SD = 3.81)
Identified Regulation IDEAS course	17.92 (SD = 1.80)	16.95 (SD = 1.45)	17.41 (SD = 1.78)
Identified Regulation Course X	14.31 (SD = 2.68)	14.57 (SD = 2.42)	14.98 (SD = 2.73)
External Regulation IDEAS course	8.65 (SD = 3.52)	9.13 (SD = 2.64)	10.02 (SD = 3.40)
External Regulation Course X	14.10 (SD = 3.74)	13.03 (SD = 3.27	14.11 (SD = 3.39)
Amotivation IDEAS course	7.17 (SD =2.35)	8.13 (SD = 2.52)	7.98 (SD = 2.65)
Amotivation Course X	10.94 (SD = 3.35)	11.38 (SD = 2.93)	10.96 (SD = 3.46)
Curiosity IDEAS course	21.83 (SD = 2.54)	20.97 (SD = 2.96)	21.17 (SD = 2.46)
Curiosity Course X	17.17 (SD = 4.39)	17.22 (SD = 3.70)	18.00 (SD = 3.95)

Results from the First Assessment

With the first administration of the assessment, the scores for the IDEAS course were significantly higher than those of Course X for intrinsic motivation with a very large effect size: $t(47) = 8.77$, $p < .01$, $d = 1.27$. The scores for identified regulation showed the same pattern with the IDEAS course significantly higher than Course X with a very large effect size, $t(47) = 8.46$, $p < .01$, $d = 1.22$, as did curiosity, $t(47) = 6.57$, $p < .01$, $d = .95$. For external regulation, the scores for Course X were significantly higher than those for the IDEAS course with a very large effect size: $t(47) = -8.26$, $p < .01$, $d = 1.19$. The scores for Course X were also significantly higher than those for the IDEAS course for amotivation with a very large effect size; $t(47) = -7.90$, $p < .01$, $d = 1.14$. Given that this assessment was done in the second week of the course, these scores could be more reflective of students' perceptions of what each course would involve and what was going to come in future classes, rather than what had actually occurred to promote intrinsic or extrinsic motivation and curiosity. However, the very large effect sizes show that the magnitude of the differences were large and therefore important [9].

Results from the Second Assessment

There was a decrease in the number of respondents for the second administration of the assessment. There were also some differences in the mean scores for the IDEAS course and Course X. Mean scores for intrinsic motivation, identified regulation and curiosity slightly decreased for the IDEAS course while simultaneously, external regulation and amotivation slightly increased. With Course X, intrinsic motivation, identified regulation, curiosity and amotivation slightly increased while external regulation simultaneously decreased. This could be a reflection of the decrease in sample size favoring those with a particular perspective or of mid-semester pressures. Regardless, the overall differential pattern for motivation and curiosity between the two courses continued.

The scores for the IDEAS course were again significantly higher, with large effect sizes, than those of Course X for intrinsic motivation; $t(36) = 6.08$, $p < .01$, $d = 1.00$, identified regulation; $t(36) = 4.83$, $p <.01$, $d = .79$, and curiosity; $t(36) = 5.61$, $p < .01$, $d = .92$. On the other hand, the scores for Course X were again significantly higher, with large effect sizes, than those of the IDEAS course for external regulation; $t(36) = -6.37$, $p < .01$, $d = 1.05$ and amotivation; $t (36) = -5.76$, $p < .01$, $d = .95$.

Results from the Third Assessment

With the third administration of the assessment, paired samples t-tests showed that the scores for the IDEAS course continued to be significantly higher, with large effect sizes, than those of Course X for intrinsic motivation; $t(53) = 5.58$, $p < .01$, $d = .76$, identified regulation; $t(53) = 5.67$, $p < .01$, $d = .77$, and curiosity; $t(53) = 5.90$, $p < .01$, $d = .80$. Conversely, the scores for Course X continued to be significantly higher, with large effect sizes, than those for the IDEAS course for external regulation; $t(53) = -7.17$, $p < .01$, $d = .98$ and amotivation, $t(53) = -5.77$, $p < .01$, $d = .79$. With this third assessment, it is noteworthy that while still large, the effect sizes for the differences between the two courses were, overall, lower than the effect sizes of the previous two administrations of the assessment, suggestive of some type of moderating effect.
Paired samples t-tests were used to compare the first with the third assessment. There was no significant increase in intrinsic motivation, identified regulation, amotivation, and curiosity in either type of course over the course of the semester. There was, however, a significant increase with a moderate effect size for external regulation from the first to the third assessment with the IDEAS course; $t(41) = 2.56$, $p < .05$, $d = .39$, but not for Course X. These findings raise the issue of the role of preconceptions about courses and their content in ongoing motivation and curiosity.

Students' Perceptions of the Seven Course Attributes

As noted previously, at the end of the course, students were surveyed about their perceptions of the seven course attributes given in both their IDEAS course and Course X. This approach was adopted rather than relying solely on faculty report because the students' perceptions of whether or not they worked on a "real problem," for example, was more important to their affect than the source of the actual problem. As can be seen in Table 2, the IDEAS courses matched well with their attributes, with the possible exception of whether or not students made a physical artifact. It should also be noted that in one of the courses, students designed a product that could be anything including a bowling alley or an app, so not all students worked on a physical prototype. While Course X was typically different from the IDEAS course, it is clear that the uniqueness of IDEAS may be due to the combination of all seven attributes, not any one of them, since they are clearly present in many other courses. The university where this study was conducted prides itself on a low student to faculty ratio, so it was not surprising that both Course X and IDEAS turn out to be "small". Only one IDEAS course is routinely much larger than 16 students.

Table 2: Summary of Course Characteristics

	IDEAS course	Course X
Course was voluntary?	100% yes	45.2% yes
Physical artifact was made?	64.3% yes	23.8% yes
Work motivated by "real world" problems?	93.0% Strongly Agree/Agree	69.1% Strongly Agree/Agree
Encouraged to apply broad perspectives?	97.6% Strongly Agree/Agree	42.9% Strongly Agree/Agree
Encouraged to use an open process?	95.2% Strongly Agree/Agree	40.5% Strongly Agree/Agree
Students in class were from multiple disciplines?	100% yes	57.1% yes
Class size	Mean: 31	Mean: 28

Implications and Conclusions

Results from the current study suggest that students were more intrinsically motivated and curious while taking the IDEAS course, compared to Course X. While it might seem intuitive that students would have higher intrinsic motivation scores due to the voluntary nature of the IDEAS course, Organismic Integration Theory suggests a more nuanced relationship [18]. Internalization of what could be extrinsically motivated actions seems to come from contexts where individuals are supported in feeling competent, experience a sense of connectedness to others, and have encouragement for autonomy. Beyond their voluntary selection, the IDEAS courses provided opportunities for close communication with industrial partners, along with professors, as they worked together to solve a "real world" problem. This encouraged students' feelings of belongingness. Working in multiple ways to generate solutions to problems without pre-determined solutions encouraged both feelings of autonomy and competence. This "open process" was clearly more prevalent in IDEAS courses than in the student-selected Course X as seen in Table 2. Further, the higher curiosity scores from the IDEAS courses supported Deci's [5] views that higher levels of competence lead to greater curiosity.

The consistently higher levels of intrinsic motivation and curiosity could also be the result of the IDEAS courses dealing with real-life situations of interest to students. As noted previously, interest can spark curiosity [13]. Implications for courses desiring to increase engineering students' intrinsic motivation and curiosity, ultimately leading to an "entrepreneurial mindset," point to course content including relevant problems of interest to students, encouraging an "open process" throughout their solution.

The lack of significant change in intrinsic motivation, identified regulation, amotivation, and curiosity in either type of course throughout the semester is of particular interest and could be the result of a number of factors. One explanation could be students' prior views of the courses, similar to their preconceptions about concepts taught. These views might be based on knowledge of the curriculum or previous students' assessments of the courses. Whatever the source, they may act as a filter while students are in those courses, affecting their motivation and curiosity. Just as with other misconceptions, differing methods of instruction may be needed to alter them.

Limitations of the Study

There were a number of limitations in this exploratory study. First, a small sample of convenience from one institution of higher education was used. Future studies should use a larger, random sample, hopefully including other institutions that have comparable courses. A larger sample size will enable researchers to see if these findings remain consistent. Additionally, varied numbers of students finished each assessment. Future research should work to increase more consistent completion of all assessments.

Second, while there were advantages to students self-selecting a comparison course (designated Course X in the current study), it meant that multiple kinds of courses were being compared with the IDEAS course. Because students did not list the name of Course X, the researchers did not know how many different courses were being compared to the IDEAS course. Future research should confine students' selection of a comparative course to either another engineering course or a course outside of the major and have students report its name. This would allow for some comparative analysis. This would also enable researchers to examine the kinds of courses designated as Course X to determine if there are any commonalities that could be impacting students' intrinsic motivation and curiosity. Finally, another limitation in the study was that results came from students' self-report. Something beyond a self-report assessment should also be considered, as recommended by Arnone et al [(1)].

Conclusions

While preliminary, these findings warrant further investigation. Future research should seek to obtain a more nuanced understanding of what it is specifically about taking the IDEAS studio course that ignites curiosity and maintains higher intrinsic motivation. One possible area to research is the impact of making an artifact. A more direct connection between curiosity and the "entrepreneurial mindset" should also be made, possibly incorporating an entrepreneurial attitude assessment. Finally, longitudinal designs should be used to focus on how motivation, curiosity and the entrepreneurial spirit can be maintained over time.

Acquiring a better understanding of how course type and the learning environment impact engineering students' motivation and curiosity could help unlock the keys to encouraging innovation and the "entrepreneurial mindset".

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