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Designing Undergraduate Design Experiences— A Framework based on the Expectancy-Value Theory*

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Although the need for infusing design experiences throughout the undergraduate engineering curricula is widely recognized, designing a good design experience is a challenge for the instructors. A well-constructed design project may excite the students and enhance their motivation and learning experience significantly. At the same time, a poorly constructed design project may in fact reduce student motivation. Despite the importance of design experiences, there currently is a lack of systematic frameworks to help instructors in core engineering courses. This paper addresses this gap by presenting a conceptual framework based on the expectancy value theory of achievement motivation. The expectancy value theory is based on two important factors that affect students' task-related motivation: expectancy, which is an individual's belief about how well he/she will do on upcoming tasks, and values, which are the reasons/incentives for completing a task. The framework is illustrated using a Systems Dynamics course taught at Washington State University. An assessment tool for the course based on the expectancy value theory is presented in the form of a survey. Statistical analysis of the outcomes of the survey for one semester is presented. The assessment tool presented in the paper can be used for evaluating the effectiveness of the design project and identifying avenues for improvement.

Keywords: undergraduate education; design projects; expectancy-value theory

1. Introduction—design experiences in undergraduate education

During the past decade, various reports have highlighted a wide range of problems with engineering curricula [1–5], including narrow technology-oriented, lecture-dominated coursework. This has resulted in reduced interest in engineering careers and low student-retention in science and engineering. A number of ways of addressing these challenges have also been suggested. Examples include research experiences for undergraduate students [6], collective learning [7], cooperative learning [8], project-based learning [9], competency-based learning [10], service learning [11–13], experiential learning [14], and the use of course journals [15, 16].

Project-based learning is gaining significant importance in undergraduate engineering curricula as a means to improve student learning. In particular, design projects that infuse elements of synthesis into existing analysis-oriented courses are suggested as tools for addressing some of the problems with traditional engineering education [9]. From a pedagogical standpoint, design-oriented projects not only improve students' knowledge of core concepts but also improve their abilities to tackle open-ended problems. The use of design-centered projects in undergraduate courses provides a number of benefits such as increased levels of excitement and fun, and increased student motivation. These factors have a positive impact on the retention of students in science and engineering.

Although design projects are attractive from a pedagogical standpoint, their effectiveness is significantly dependent on how design experiences are structured. This includes appropriate choice of technical project, the aspects to be analyzed and/or designed, the deliverables, the group size, cooperation/competition mechanisms, etc. The choices are also dependent on aspects such as the learning objectives, student's prior knowledge, students' long-term goals, topics covered. Inappropriately-structured design experiences may lead to unreasonable expectations, wasted effort, frustration among students and instructors, and thereby result in a negative effect on learning. The frustration may also cause instructors to derive incorrect conclusions such as 'design projects are not suitable for me because my course is highly mathematics oriented'. Hence, there is a need for a systematic framework for structuring the design experiences in undergraduate courses.

Our goal in this paper is to present such a framework to support instructors in designing appropriate design experiences. The framework is based on the expectancy-value theory [17–20] of achievement motivation. The framework is illustrated using an example from an undergraduate mechanical engineering course on system dynamics. A survey instrument along with an analysis of data obtained for the

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class offered at Washington State University are presented.

2. A Framework for design experiences based on the expectancy value theory

2.1 An overview of theories on achievement motivation

The word motivation is derived from the Latin word 'movere' which means 'to move'. Achievement motivation refers to 'motivation relevant to performance on tasks in which standards of excellence are operative' [21]. During the past few decades, there have been significant efforts on identifying the factors that affect achievement motivation. Hulleman et al. [22], Wigfield et al. [21] and Eccles and Wigfield [18] provide comprehensive reviews of the theories for achievement motivation. Current research is primarily focused on the influence of individuals' beliefs, values, and goals on motivation. According to Eccles and Wigfield [18], these theories can be classified into four categories—a) theories focused on expectancy, b) theories focused on task value, c) theories that integrate expectancies and values, and d) theories integrating motivation and cognition. Expectancy refers to an individual's belief about how well he/she will do on upcoming tasks, and values refer to the reasons for doing an activity.

Theories focused on expectancy relate the individuals' beliefs about their competence to their motivation for completing activities. These theories include self-efficacy theory and control theories. Self-efficacy theory was initially proposed by Bandura [23], who defines self efficacy as individuals' confidence in their ability to organize and execute a given course of action to solve a problem or accomplish a task. Based on the self-efficacy theory, the factors that determine an individual's perceived self-efficacy include previous performance, vicarious learning, verbal encouragement by others, and one's psychological reactions. The underlying theme in control theories is that individuals who believe that they control their achievement outcomes should feel more competent [24]. While self efficacy and control theories explain the impact of competency and expectancy beliefs, they do not explain why competent people choose not to engage in achievement related tasks. This aspect is addressed by the theories focused on task value. The underlying concept in task-value related theories is that different tasks have different benefits for individuals, and individuals have greater motivation to engage in tasks that have higher value. The theories under this category include intrinsic motivation theories, interest theories [25], and goal theories [26]. Intrinsic motivation is related to the enjoyment or pleasure that an individual receives from participating in an activity whereas extrinsic motivation is related to the reward received as a result of completing the activity. Intrinsic motivation theories focus on activities carried out for their own sake and out of interest in the activity. These include self-determination theory [27] and flow theory [28].

Theories that integrate expectancy and value constructs include attribution theory [29], expectancy-value theory [18], and self-worth theory [30]. According to the attribution theory, an individual's attributions (including ability, effort, task difficulty and luck) relate to their success and failures, and subsequently influence motivation. Expectancy-value theories link achievement performance, persistence, and choice most directly to individuals' expectancy-related and task-related beliefs (such as perceptions of competence, difficulty, and individual goals). Self-worth theory is based on individuals' tendency to establish and maintain a positive self-image within the group or the classroom. Finally, theories that integrate motivation and cognition explore the links between cognitive aspects such as self-regulation and learning strategies. In this paper, the discussion is primarily focused on the expectancy-value theory.

2.2 An overview of the expectancy value theory

The underlying premise of our framework is that appropriately structured design experiences increase students' motivation, thereby increasing their learning. Hence, human motivation theory can be used to explain the impact of introducing design projects into undergraduate engineering courses. Although academic discussions of human motivation evolved over the last century, educational research in this area has grown tremendously in the last two decades especially with investigations of achievement goal orientations [31] and expectancy-value model of achievement motivation [17-20]. The expectancy-value theory of motivation is grounded on the claim that 'individuals choose behaviors based on the outcomes they expect and the values they ascribe to those expected outcomes' [32]. In order words, the expectancy value theory posits that individual motivation for a task depends on perceptions about the odds of success on the task and the value of completing the task:

Motivation (M) = Perceived Probability of Success in a Task × Subjective Task Value

The expectancy-value theory of motivation has been used in many engineering education studies [31, 33]. For example, Matusovich et al. [33] used this theory of motivation to understand how students, in fact, come to choose engineering as a discipline. They found that 'different patterns exist in the types of value or personal importance that participants assign to earning an engineering degree'. It appears that these differential patterns of beliefs may significantly mediate the more proximal beliefs that students hold while undertaking engineering courses. According to Eccles and Wigfield [18], students' expectancy beliefs and subjective task values directly influence performance, effort, persistence, and task choice. This motivation-performance link explains why appropriately-defined engineering design projects can improve student learning in engineering core courses. At a fundamental level, faculty can (1) increase student beliefs about their odds of success through the proper structuring of a project and mentoring as the project is ongoing, and (2) increase student perceptions of project value by ensuring that the project has a 'real world' feel and connection to engineering topics beyond those of an individual core course.

The expectancy-value theory of motivation highlights two factors (see Fig. 1) that affect achievement-related choices made by individuals: a) expectancy for success, and b) value. The expectancy for success is an individual's belief about how well he/she will do on upcoming tasks. If the individual thinks that the activity is too difficult, then he/she will have less motivation to carry out that task. If an individual is confident about completing the task, he/she is more likely to complete it. Accordingly, design experiences should be structured in a way that maintains high expectancy for students' success. This involves finding out students' prior knowledge and skills before starting the design activity. If an instructor starts with incorrect assumptions about students' skills, he/she may create a design project that is overly difficult for the students. In such a case, the students' expectancy for success may be low, and hence, the motivation will also be low.

Within the framework of expectancy value theory, values refer to reasons (or incentives) for doing the activity. Value has four components: a) *attainment value*: personal importance of doing well on the task, b) *intrinsic value*: enjoyment that an individual derives from performing the activity, c) *utility value*: how well a task relates to current and future career goals, and d) *cost*: the negative aspects of engaging in a task. Similar to the expectancy for success, good design projects have high attainment, intrinsic, and utility values to the students and low cost.

3. Designing a design experience for an undergraduate systems dynamics course

3.1 Overview of ME 348: system dynamics at Washington State University

In this section, we present an example course and discuss how expectancy value theory was used as a framework to structure the design projects. ME 348 (System Dynamics) is a required course for mechanical engineering students at Washington State University. The catalog description of the course includes 'Fundamentals of vibration analysis, control systems, system modeling and dynamics analysis'. The course has three main objectives: a) to provide students with a review of dynamics, b) to instruct students in the use of modeling mechanical, electrical, thermal, and fluid engineering system, and c) to introduce students to the analysis of linear dynamical systems, vibrations, and control systems. The textbook adopted in the course is [34]. The class is held in 50 minute timeslots for three days a week for 15 weeks.

Prior to Fall 2010, the focus was primarily on delivering technical concepts and assessment using regular homework and exams. No design projects were conducted in this course, which resulted in frequent complaints from the students about the heavy math content with little connection to prac-

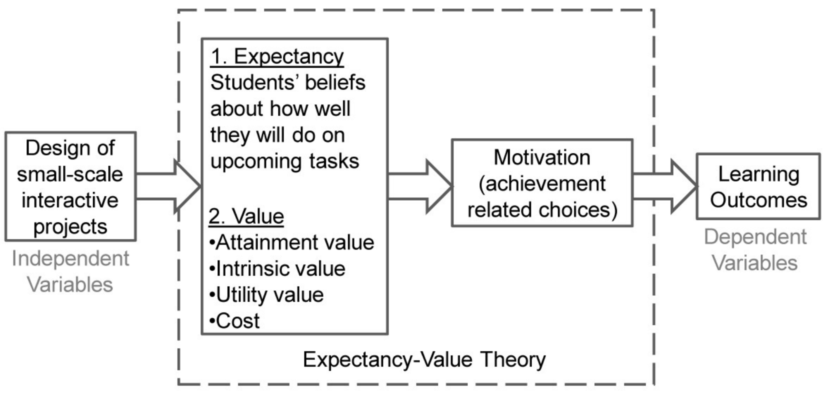

Fig. 1. Using expectancy value theory to understand the effect of independent variables associated with structuring design experiences on learning outcomes.

tical engineering design problems. To address this recurring feedback from the students, the instructor decided to include collaborative design projects in the course. Design projects were included in ME 348 during Fall 2010 to help the students in relating the course material to real engineering problems. During the Fall semester, there was one section of ME 348 with 60 students. The projects were open-ended design problems and the students were asked to pick their own physical systems for analysis. To provide some direction to the students, a sequence of general steps was provided such as development of a free-body diagram, creation of a mathematical model using state-space representation, transient response analysis, steady-state response analysis, etc. The students picked a variety of systems ranging from simple pogo sticks to motorcycle suspension systems.

Based on feedback from the students, it was found that the projects were highly effective in engaging students and increasing their motivation to learn the core concepts. However, the primary challenge was that it was difficult for the instructor to devote significant amount of time to each group to provide detailed feedback such as helping them with modeling, checking their equations, making sure that the parameter values are correct. This was mainly due to the large class size and the choice of very different projects by different groups. Hence, the instructor chose a different approach during Spring 2011—to use the same physical system for all the teams. The instructor used the concepts from the expectancy value theory to choose the physical system and to determine the problem scope and collaboration structure. The details are provided in Section 3.2.

3.2 The design project—from an expectancy value theory perspective

During Spring 2011, there were two sections of this course concurrently taught by the instructor. Section 1 consisted of 75 students in the main campus in Pullman where the instructor is located. Section 2 consisted of 15 students in the Bremerton campus connected via a live videoconference link.

Students were asked to undertake a project in groups of four. The project was to analyze and design the suspension system of an off-road vehicle. A specific off-road vehicle, called the Rally-Fighter[1], was selected (shown in Fig. 2). The Rally Fighter was selected because its design is open-source, making it easier to find information about the components used in the vehicle. There is significant amount of documentation and a number of videos available online to help students with their project. In addition to this, the instructor provided additional reading materials on suspension systems and mathematical modeling of vehicle dynamics using half-car and full-car models. The instructor was able to dedicate various lectures to the project because all the teams were designing a single system.

Fig. 2. The Rally fighter (http://www.local-motors.com/rallyFighter.php).

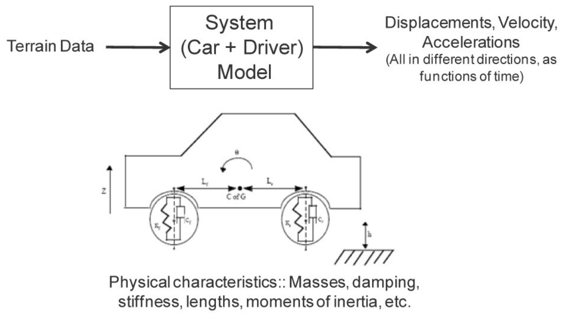

Fig. 3. Illustration of the model.

The project was scaffolded to help students achieve their goals. Specific deliverables were assigned for each week (see Table 1). During the first week, the students were asked to gain an understanding of the vehicle and the design requirements. The second week involved developing a free-body diagram and the equations of motion. A 2-D half-car model (shown in Fig. 3) was developed. During the third week, the equations were used to derive transfer functions and state-space representations of the model. The deliverable for the fourth week was a driver model that controlled the acceleration of the car. The goal of the driver model was to maximize the ride quality while traveling on an uneven terrain. The mathematical models are implemented in Matlab during Week 5 and the design parameters are optimized during Week 6. Finally, the models are verified in Week 7 and submitted in Week 8.

In order to design this project, the instructor had an hour discussion with the students in the classroom to understand their expectancies and the four aspects of value in the expectancy value theory. The

[1] http://www.local-motors.com/rallyFighter.php

Table 1. Overview of the project carried out in ME348: Systems Dynamics (Spring 2011)

Designing the Suspension System for an Off-Road Vehicle—Rally Fighter
Objective: To apply the concepts of system dynamics to a real-world mechanical engineering system by designing and analyzing the 'Rally Fighter' suspension system
Week 1: Background research and idealization—understanding the problem Week 2: Force analysis—free body diagrams and equations of motion Week 3: Vehicle model—Transfer functions and block diagrams Week 4: Feedback Control—driver model Week 5: System implementation—develop models in MATLAB Week 6: Optimization of parameters and model adjustment Week 7: Verification—submit model for testing and comparison Week 8: Final submission

project primarily requires mathematical skills to formulate the problem in terms of differential equations and programming skills to implement the system. Based on the discussion, the instructor learned that the students have the basic mathematical skills necessary to develop free body diagrams, to develop differential equations of mechanical systems, and to solve the differential equations using the Laplace transform approach. The instructor also learned that the students are familiar with programming either in Matlab or another programming language. Hence, the instructor was confident that the students' high expectancy in both mathematical skills and Matlab programming would result in high levels of motivation.

As discussed in Section 2.2, the four aspects of value include attainment value, intrinsic value, utility value, and cost. The attainment value, which is the personal importance of doing well on a task, is related to the direct outcome of the task. One of the direct outcomes of the project is the project grade. While the level of attainment value associated with this project varies across the class, all students are interested in maximizing their grade. Hence, the impact of student performance on the grade directly affects their motivation. The intrinsic value, which is related to the enjoyment that an individual gets from performing the activity, is dependent on whether the students enjoy working on the project or not. To ensure that the students have fun while working on the project, a competition at the end of the semester was planned. Within this competition, all teams race their model cars on a virtual track. The model that finishes the track in the least amount of time while maximizing ride quality wins the competition. Additionally, Rally Fighter is a unique sporty all terrain vehicle which was found to be inherently interesting for the students. The utility value depends on how well the project relates to the students' current and future career goals. For the group of mechanical engineering students, the relevance of project to a mechanical system such as an automobile is expected to have a positive effect on their motivation. Finally, the cost aspect is related to the effort required to complete the project. If the time investment in the project is very high to the extent that it affects their performance in other classes, the students may be less motivated. To distribute the effort among different students, the project is carried out in a group setting. The students are asked to work in teams of up to four. A higher group size is expected to increase the coordination effort and reduce the individual participation, thereby having an adverse effect on motivation.

Having designed the project by considering the different aspects of expectancy and value, the project was executed, and a summative assessment was performed at the end of the semester. The details of the assessment are discussed in Section 4.

4. End-of-semester assessment of the design experience

4.1 A survey instrument based on the expectancy value theory

The students were given an anonymous survey at the end of the semester. The goal of the survey was to gather information about the independent variables related to designing design experiences and their effect on the dependent variables (such as motivation and learning). The questionnaire consisted of 30 questions related to students' expectancy beliefs, their perceived value, motivation, effort, performance, and learning outcomes. Specific questions were included in the survey to assess the structure of the project. Table 2 lists the questions and a summary of the survey results. Since the project was focused on a mechanical system, questions about learning did not include electrical, thermal, and fluid systems. A total of 76 students responded to the survey. The students' overall feedback on the project was positive. Statistical analysis of the survey results are provided in Section 4.2.

4.2 Analysis of results from the survey

The 30-item survey taps motivational constructs and learning outcomes preferences. Participants

Table 2. The questions included in the assessment tool

Expectancy beliefs	**1**	**2**	**3**	**4**	**5**
1. How would you rate your proficiency in the mathematical skills needed for this project? (1 = very low, 5 = very high)	1%	4%	16%	50%	29%
2. Compared to the rest of the students in the class, how would you rate your mathematical skills? (1 = very low, 5 = very high)	1%	1%	34%	38%	25%
3. How would you rate your proficiency in Matlab? (1 = very low, 5 = very high)	24%	30%	30%	12%	4%
4. Compared to the rest of the students in the class, how would you rate your proficiency in Matlab? (1 = very low, 5 = very high)	11%	28%	39%	14%	8%
5. What was your level of confidence that you could complete the project? (1 = very low, 5 = very high)	8%	11%	33%	33%	16%
6. In terms of the difficulty, how would you rate the project in this course compared to the projects in other courses? (1 = very easy, 5 = very difficult)	0%	5%	22%	49%	24%
7. Someone in the team (which includes you) was proficient in Matlab (1 = strongly disagree, 5 = strongly agree)	8%	9%	25%	32%	26%
8. Someone in the team (which includes you) was proficient in the mathematical skills needed for this project (1 = strongly disagree, 5 = strongly agree)	0%	3%	17%	33%	47%
9. Your team was confident that you can accomplish the project (1 = strongly disagree, 5 = strongly agree)	4%	9%	18%	34%	34%
Value	**1**	**2**	**3**	**4**	**5**
10. How important was it for you to complete the project? (1 = not very important, 5 = very important)	4%	3%	8%	13%	72%
11. How much did you enjoy working on the project? (1 = not very much, 5 = very much)	11%	14%	38%	29%	8%
12. As a mechanical engineer, how useful is what you learned in this project? (1 = not very much, 5 = very much)	4%	5%	21%	42%	28%
13. How much of what you learned in this course will be used in your future career? (1 = not very much, 5 = very much)	9%	11%	32%	36%	13%
14. How many hours did you spend per week on the project? (1 = 1-5 hrs, 5 = 20+ hrs)	22%	26%	34%	12%	5%
15. Compared to other engineering courses you have taken, how much work outside of the classroom was required by this course? (1 = lot less, 5 = lot more)	0%	4%	34%	47%	14%
16. This project enabled me to learn the basic concepts of this course better than I would have through traditional homework assignments alone. (1 = strongly disagree, 5 = strongly agree)	7%	20%	21%	26%	26%
17. I believe that my participation in a design project in this course will make me more likely to retain knowledge learned in this course compared to if I did not participate in such a project. (1 = strongly disagree, 5 = strongly agree)	1%	11%	25%	38%	25%
18. On the balance, what I learned on the design project outweighs the effort I put in to completing it. (1 = strongly disagree, 5 = strongly agree)	8%	14%	34%	34%	9%
Motivation	**1**	**2**	**3**	**4**	**5**
19. How do you rate your level of motivation to work on the project? (1 = not motivated at all, 5 = highly motivated)	4%	12%	28%	42%	14%
Performance	**1**	**2**	**3**	**4**	**5**
20. How would you rate your performance compared to the rest of the class? (1 = not good, 5 = outstanding)	3%	3%	24%	46%	25%
21. How would you rate your performance in this course compared to your performance in other Mechanical Engineering courses? (1 = not good, 5 = outstanding)	5%	3%	37%	38%	17%
Structure of the Project	**1**	**2**	**3**	**4**	**5**
22. How would you rate the size of the team? (1 = too small, 5 = too big)	3%	5%	72%	12%	8%
23. How would you rate the level of structure in the project? (1 = highly open ended, 5 = highly structured)	7%	16%	38%	33%	7%
24. What kind of a project do you prefer? (1 = highly open ended, 5 = highly structured)	4%	12%	30%	34%	20%
25. How excited were you about the competition between different suspension designs? (1 = not very excited, 5 = very excited)	21%	25%	14%	29%	11%
26. How excited were you about the use of the real world design example? (1 = not very excited, 5 = very excited)	3%	3%	16%	34%	45%
Learning Outcome	**1**	**2**	**3**	**4**	**5**
27. Through this project, I learnt the basic concepts of system dynamics (1 = strongly disagree, 5 = strongly agree)	5%	7%	17%	47%	24%
28. Through this project, I learnt how to use of modeling mechanical engineering systems (1 = strongly disagree, 5 = strongly agree)	1%	8%	18%	47%	25%
29. Through this project, I learnt how to perform analysis of linear dynamical systems, vibrations, and control systems (1 = strongly disagree, 5 = strongly agree)	1%	12%	30%	38%	18%
30. What is your level of confidence in completing similar projects in the future? (1 = very low, 5 = very high)	1%	11%	26%	42%	20%
Open Ended Question	**1**	**2**	**3**	**4**	**5**
31. How can the learning experience in the project be further improved?	Free form text				

Table 3. Zero-order correlations among subscales of the survey (N = 76)

	1	2	3	4	5	6	7	8	9	10
1. Proficiency in Math skills	–									
2. Proficiency in Matlab	0.14	–								
3. Confidence—This project	0.24*	0.39**	–							
4. Confidence—Future project	0.37**	0.17	0.59**	–						
5. Motivation level	0.31**	0.12	0.43**	0.49**	–					
6. Attainment value	0.32**	0.13	0.51**	0.44**	0.43**	–				
7. Intrinsic value	0.40**	0.11	0.51**	0.48**	0.51**	0.51**	–			
8. Utility value	0.08	0.10	0.40**	0.48**	0.30**	0.40**	0.63**	–		
9. Performance	0.49**	0.20	0.49**	0.40**	0.37**	0.49**	0.32**	0.14	–	
10. Learning outcomes	0.36**	0.30**	0.55**	0.57**	0.51**	0.48**	0.55**	0.58**	0.32**	–

* $p < 0.05$, ** $p < 0.01$.

were instructed to respond on a 5-point Likert scale. Overall survey yielded a strong internal consistency alpha value ($\alpha = 0.90$). The scales (expectancy beliefs, values, performance, and learning outcomes) showed good internal consistency for the reliability analysis, yielding Cronbach's alpha (α) levels of 0.73, 0.80, 0.80, and 0.85 for the four subscales, respectively. Items or questions in the survey that measure similar constructs were combined to examine correlational analyses. For example, since items 1 and 2 measured students' proficiency in mathematical skills, these two items were combined and labeled 'proficiency in mathematical skills' as a component of expectancy beliefs. Table 3 shows the correlations between the variables.

The majority of the correlation coefficients were in the expected direction. As expected, proficiency in mathematical skills showed moderate, positive, and statistically significant correlations with all the other variables ($ps < 0.01$), except with proficiency in Matlab and utility value ($p > 0.05$). Notably, proficiency in mathematical skills was especially strongly correlated with performance in the design project. Surprisingly, proficiency in Matlab was only significantly correlated with confidence in completing the design project and the learning outcomes but not significantly correlated with all other variables. This may have been because students perceived proficiency in the use of Matlab as important only to the current design project and not highly related to future projects, their levels of motivation or the values attached to the project.

Overall, results showed that motivation is positively and statistically significantly correlated with expectancy beliefs in the use of mathematical skills and the values students attached to the project. This, in turn, correlated significantly with performance and learning outcomes, thus validating the expectancy-value theory of motivation.

One of the most revealing aspects of such a survey is the set of responses on the open-ended question asking for students' feedback on improving the design experience. About 80% of the students provided some comments related to the use of Matlab in the project. At the start of the project, the students and the instructor believed that the students' Matlab skills are adequate for the project. Hence, the expectancy was high. However, during the design project, the students realized that they have an understanding of the basic concepts of Matlab but do not have experience working on programs of the scale required for this project. Hence, they spent significant amount of time in debugging and making changes to the code. Some students suggested formal instruction in Matlab as a part of the course. Other students suggested including some examples of related projects to help them with Matlab programming. Some students also suggested reducing the need for extensive Matlab programming in the project. The instructor is considering these ideas for refining this project.

5. Closing comments

This paper addresses an important problem associated with design-centric engineering education. Although instructors are encouraged to infuse design-related activities and projects in undergraduate curricula, there is a lack of systematic conceptual frameworks to guide them in structuring such design experiences. This paper addresses this gap by providing a conceptual framework anchored in the literature on human motivation. Through an example, we illustrate how the framework can be used by instructors. The quantitative assessment tool provided in this paper can be used for evaluating the effectiveness of the design project and identifying avenues for further modifications.

Instructors generally use their judgment for structuring design projects. They take some of the factors into account implicitly, such as effort involved, relevance to the course and student interests. However, there is a risk of missing out on important factors that affect student motivation (and hence, student learning). The expectancy value theory is helpful because it makes the different components of expectancy and value explicit in the planning of design projects. The survey tool presented in this paper helps in providing student feedback to the instructors for continuous improvement. The survey is also helpful in ensuring that the assumptions that the instructor has about students' interests and competencies are indeed correct.

There are significant avenues for future research in this direction. For example, the design experience in the course discussed in this paper was designed based on discussion with students. However, a formal pre-project survey would be more valuable in identifying students' expectancies and values. Further, it was found in this course that the expectancies and values of the students may change during the project. Hence, the motivation may also change during the execution of the design project. Such changes can be recorded by performing repeated surveys during the course of the project. The survey tool presented in this paper is primarily focused on the design project. It can be extended to include an entire course, or even an entire curriculum to assess the students' motivation throughout their degree program. The survey can also be adapted to other courses.

There may be a difference between the instructors' perception of competencies, the students' own perceptions of the competencies, and the actual competencies required for a project. It is important to explore the impacts of such differences on the design experience. Moreover, the students' competencies may also increase as they work on the project and gain more experience with tools and methodologies. The framework can be extended to account for such changes.

One of the limitations of the survey presented in this paper is that it accounts only for technical competencies. It does not account for other aspects of expectancy such as team working skills, which are also likely to affect students' motivation and can be considered in the future studies. Finally, the effects of some parameters related to the design of design experiences on the expectancy and value are direct, but the effects of some other parameters such as the group size are indirect. Further studies are required to explore the effect of such indirect parameters.

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