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Student Reflections on the use of a Market Simulator in an Engineering Design Course*

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Education researchers have observed a disconnect between the goals of the current educational system and the practical application of professional skills outside the classroom. Skills such as creative thinking, knowledge of engineering science, global thinking, and cross-cultural communication should be honed in addition to technical engineering skills. These skills are often taught in engineering design courses. The purpose of this study is to evaluate student learning of market concepts in a design course, with an emphasis on the use of a market simulation tool to forecast consumer choice among competing products, by analyzing written reflections, course surveys, and project reports. Specifically, we assess the self-reported learning value of using an interactive market simulation tool in the classroom. The study employed a descriptive case study to understand the value of a market simulator in an engineering design course. Several sources of data from student reflection assignments, the "lessons learned" segment of the final report, and class surveys were collected at multiple points in the semester and analyzed through a combination of qualitative and quantitative approaches. Based on Kember's level of reflection framework, we found that students' levels of reflection changed from mostly level 2 (understanding) to level 3 (reflection) between the fifth and thirteenth weeks of the course. We did observe a decrease in mentions of the value of the market simulator and an increase in acknowledging difficulties, which may show how students' response to the market simulator changes as they reflect again and become more aware of the complexity of the design process as it relates to the market. The key takeaways in the teams' final reports showed parallels with the course objectives. Our results show reflective practice is an effective instructional strategy for students to develop holistic self-regulated learning and professional skills. Themes that pertain to the concepts in the design course emerged and became significant indicators of understanding and critical reflection of the design process as a whole. Team reports on "lessons learned" signify that prior reflective practice encourages students to be more aware of their learning outcomes and the importance of the use of learning tools to achieve these goals.

Keywords: market simulator; engineering design; professional skills; reflection

1. Introduction

One of the main goals of higher education is to sufficiently equip students with relevant knowledge, skills, and attitudes as they enter and navigate the professional world. Engineering curricula have focused on developing technical skills that are needed in the professional space, but graduates must also learn the professional skills required while on the job [1]. According to ABET, the organization that accredits higher education engineering programs, universities should teach undergraduate engineering students professional skills such as communication, teamwork, ethics and professionalism, engineering within a global and societal context, lifelong learning, and knowledge of contemporary issues as part of their engineering curricula [2]. Integrating these professional skills into engineering education becomes more important as engineering graduates become more collaborative and interdisciplinary in their work [3]. However, researchers have observed a disconnect between the goals of the current system of education and the practical application of professional skills outside the classroom [4]. As engineering is a field that frequently involves designing systems, design courses are often the most suitable parts of the engineering curriculum to teach "design in context" and professional skills. Further, it is imperative that engineering graduates can adapt

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to a changing world. This, researchers believe, is necessary to produce holistic designers and engineers [5].

One proven educational method that has been used to improve the retention and practice of both technical and professional skills among students is the use of reflection. Reflection is used to help students self-direct their learning and achieve a deeper understanding of the content they are expected to learn [6]. In fact, the use of reflection in design education is recommended to allow students to further understand the processes and all the elements involved in a design [7]. For example, in their study of how students engage in design education activities, Turns et al. [8] found that students experienced higher learning gains and higher retention of information when they participated in reflection activities as they learn.

The present article analyzes reflections focused on the implementation of a market simulator in a design course to understand and learn about students' understanding of market-driven design in engineering design education. This study aims to answer the following research questions: (1) What key themes do students identify through reflection of their use of the market simulator? (2) How do students' engagement and effort correspond with these key themes?

2. Background

2.1 Design Education

The engineering industry has noted that engineering education focuses much of the curriculum and instructional time on teaching technical skills; this renders students unprepared for the professional challenges faced in the industry [9]. The desired skills in design education for engineers in the twenty-first century have shifted to skills such as creative thinking, knowledge of engineering science, global thinking, and cross-cultural communication [4]. Specifically, for engineering design it is important that market training is incorporated into educational programs to help engineering students understand how the market can influence design requirements, rather than only focusing on research and development for technical performance [3]. Further, it has been reported that recent engineering graduates have had an overly technical bias in their curricula retention, creating shortcomings in their skill sets, specifically towards business and market elements of design [9, 10]. Some researchers posit that focusing on the multidisciplinary context in students' design projects will better prepare them for the many elements that go into designing outside of an educational setting [11]. As problem-solving becomes more complex and requires acknowledging and learning various areas of expertise in today's world, engineers must possess well-rounded professional skills to be able to work on dynamic teams.

To provide a holistic design education, there is a need for students to understand how scoping a problem encourages exploring knowledge, leads to understanding the implementation of design, incorporates interdisciplinary teamwork, includes the perspective of design, and creates a stimulating environment for deeper learning [7]. On the part of engineering instructional design, creating a design problem that incorporates these factors is challenging but believed to be necessary towards a successful design education. Simulating the experience of real-world design problems in the classroom allows students to try different ideas and to make mistakes without the stress of an employment status [12]. So, students need to be more exposed to open-ended problems that involve discussion of the design process in ways that resemble what they will encounter in the industry.

2.2 Reflection in Higher Education

Learning is a covert activity that is assessed through overt means [13, 14]. In other words, there are representative stages of what a person consciously and unconsciously does when learning. However, there are some aspects of learning that are challenging to assess by observing behavior. Several studies have been designed to explore how students' thinking about particular concepts change over time [15]. One of the most common ways to document changes in learning and understanding is through reflection activities. Several studies have found that students go beyond surface to deep learning when they reflect often throughout the duration of a course [16]. In fact, one study recommended that an appropriate mode of helping students reach the transformative stage of learning [17] is through the use of reflection as a tool. Reflecting as they learn can help students to make sense of the content and therefore achieve a deeper understanding of the material.

In this study, we refer to reflection that is defined as a student's temporary pause in the consumption of new educational material to consider what they may have learned up to that point in a class [18]. Reflection allows students to slow down and think through experiences, enable "self-directed" learning, and help students make sense of complicated materials [6]. Reflection practices that are incorporated in the instructional design provide students the opportunity to develop self-directed learning techniques and professional skills [19, 20].

Reflection activities have been used extensively in several disciplines. For example, in medical education creating opportunities to reflect are integrated into the curricula to promote students' abilities of self-directed learning and professional competence [21]. Critical reflection in an educational setting such as in the medical field can primarily be learned by practice, so the curricular design should incorporate more opportunities for reflection to increase its effectiveness. The use of the reflective practice has allowed medical professionals to diagnose in complex cases more accurately, showing the effectiveness of the reflection practice [21]. The integration of reflection allows students to develop their metacognitive skills and, thus, overall lead to a better understanding of patients.

Further, reflection is a driver of personal development because it emphasizes the lessons learned from successes and failures in a student's educational experience. By using reflective learning, students can develop strategies on improving their ability to learn, apply their learning, and thereby overcome challenges in their learning, which as a result helps students become independent learners [22]. Such skills enable students to find ways to adapt and learn from brand new experiences as they enter the professional world.

2.3 Reflection in Design Education

As students go through the design process in their design courses, there are opportunities to integrate reflection into the instruction. To achieve a holistic design education, engaging students in reflection throughout the design process is recommended [7]. It is then important for students to reflect not only on the overall design itself but also on how they set their strategies to hit the goals for each process in the design. In turn, students have the opportunity to understand better what problem-solving skills are required to reach these goals. Using reflection to have students focus on the steps of the design process allows them to understand beyond what the material requires them to learn throughout the design courses. In a study conducted by Bailey [23], they found that when students were presented with reflective prompts aimed at assessing their design process knowledge students would reflect on their growing abilities to engage in broader conversations around what it really means to design with a context in mind. The study also reported an increased level of appreciation for how engineers should design with people in mind, their processes should be aimed at engaging with the end-users and that it is acceptable for engineers to refine their design once the users provide feedback on the product. These findings support the goal of our study which is to showcase how students' conceptions of design increase when they reflect on their engagement with the content specifically designed using market related features.

Practicing working on a team in design education is also important to prepare students for the teamwork and communication demanded in the industry. In a study by Turns et al., [8] using a reflection software called the Reflective Learner, students who used the software in an engineering design course were able to understand roles, responsibilities, and goals of activities better, and the software created a positive impact on teachers and students in terms of achieving the learning goals. Reflecting on teamwork in design education shows that students learn the characteristics of a high-performing team, which are good communication, leadership, and project management [24]. These are some of the professional skills demanded by today's industry.

This study has noted that both students and teachers had a positive response to reflection in the context of education. Thus, reflection in the future can be used as an effective tool to help students self-direct their educational experiences [25, 26]. This is in line with the major goal of this study, which is to utilize reflection practices and course assessment outcomes as tools to understand students' overall learning, particularly through the use of a market simulator in an engineering design course.

3. Methods

This study utilized a single descriptive case study with multiple embedded units. A descriptive case study is typically used to describe a phenomenon and the context in which it occurs [27, 28]. In descriptive case studies, the intent is to highlight overarching connections among different sources of data pertaining to the phenomenon under investigation [29]. The main benefit of this type of case study lies within its ability to draw data from many sources, where each source is of equal importance in providing in-depth information relevant to the topic being studied [30]. In addition, findings from a descriptive case study tend to have implications that can be applicable to other cases or fields of study [29]. Several sources of data, qualitative and quantitative, were collected and analyzed to understand the usefulness and effectiveness of an interactive market simulation tool. These data sources include two of the course's weekly written reflection assignments, which were analyzed for depth of reflection as well as themes present, the lessons learned section of the final project reports, and two surveys administered during and after an engineering design course. These assessments were part of their course work for Design VI.

3.1 Context of the Course

Design VI is the sixth course in the eight-course Design Spine curricular sequence, typically taken during students' sixth semester at Stevens Institute of Technology (SIT) [31]. The first five semesters of courses featured in the Design Spine are shared courses across all engineering disciplines at Institution, and they use topic-focused open-ended projects to integrate design experiences into students' education. Design VI is the first course in the Design Spine to divide the students by specific discipline to focus their learning towards major-specific development lessons. The student participants in this study are enrolled in the Engineering Management and Industrial and Systems Engineering majors.

The Design Spine sequence has a goal of increasing focus on problem-solving, communication, project management, ethics, the economics of engineering, teaming, and industrial ecology [31]. The Design VI course allows students to work in teams of three to four members to develop a product that solves a problem they identify while incorporating the professional goals of Design Spine. The goal of the course project is to develop a successful product for the market, while the students gain knowledge and skills regarding design processes and develop professional skills through teamwork and assignments.

During Week 5 of the course, a market simulator was introduced to expose the students to the mechanics of how the market affects product design, and vice versa, giving students a high-level snapshot of how their products may fit into the real world. The market simulator was designed specifically for this course, to enable students to see how successful their product would be in comparison to competitors [32]. The simulator requires students to input information, determined through a combination of internet research and educated assumptions, about competing products on the market and customer preferences. For example, one student project team designing a desk fan used this tool to investigate how consumers would be expected to make choices if their product were competing against existing fans that can be purchased in stores or online. They are able to use this to understand how changing their fan's attributes, such as the air flow rate or price, would affect their market success and profits, as consumers choose between their new fan and the competing fans. The input interface for this example is shown in Fig. 1, and the output side of the interface shows plots of expected

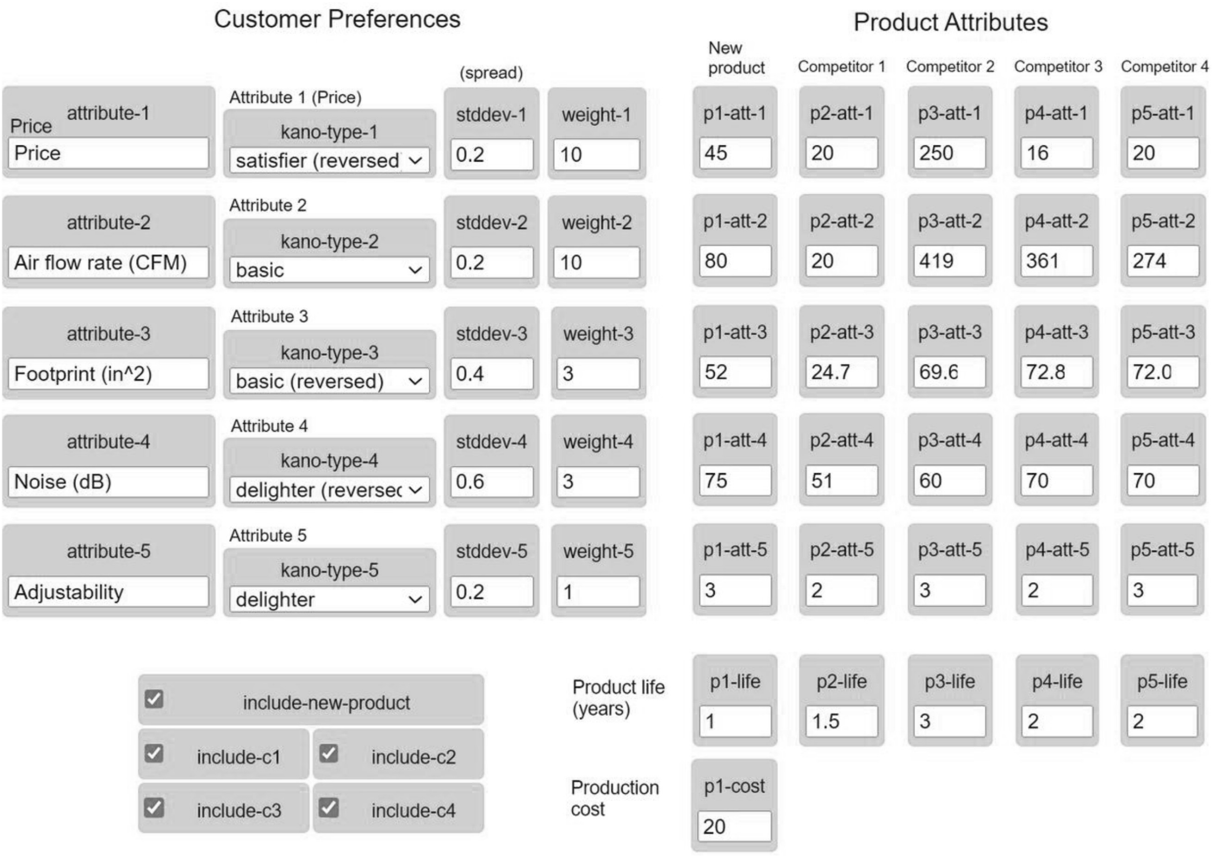

Fig. 1. Market simulator input interface, where users enter consumer preferences and competitor attributes.

market shares and profits. Throughout the course, weekly reflections were assigned with prompts focused on topics learned that week in the course. The reflections from Week 5 and Week 13, which specifically ask about using the market simulator, are used as the main source of data for this study.

3.2 Participants

The participants in this study were 23 students majoring in Engineering Management and Industrial and Systems Engineering (EM/ISE) enrolled in Design VI SIT. All students in EM/ISE are required to take this course, and it typically fits into their sixth semester of the undergraduate degree. Among the students, 20 were enrolled in the Engineering Management major, and three were enrolled in Industrial and Systems Engineering, which was a new program in that year. Among those who participated, 43% of the students identified as female and 35% as non-white. The study was approved by the university Institutional Review Board under protocol number 2017-016 (21-R1), and all participants signed informed consent forms prior to any data collection.

3.3 Theoretical Framework

This study is guided by reflective practice. Reflective practice, coined by [15], is described as interactive process through which thought and action are interlinked. In professional settings, it is the approach that enables practitioners to develop critical skills, enhance their professional growth, and grow their broader understandings of their impact on the workplace. In classroom settings, reflective practice has significant impact on student learning. When students engage in reflective practice, they develop their own knowledge through actively analyzing their experiences and actions [33–35]. This act of reflecting on their learning leads to deeper cognitive engagement with the content and the learning process more broadly [35]. In this study, reflective practice was integrated in the Design VI course assessments through the use of weekly reflection assignments. Reflective practice, as conceived by Kember et al. [36] was also used to guide the analysis of the data.

3.4 Data Collection and Analysis

3.4.1 Reflection Prompts and Guidelines

In this study, the main goal was to capture students' reflections about the market simulator used in the class, which occurred at two points during the semester. The market simulator was a new experience for the students, providing a meaningful opportunity for students to reflect. In Week 5 of the course, the market simulator was introduced through an interactive one-hour session, during which the instructor briefly explained the tool and then the student teams used it in the context of their project ideas. Following that class session, students were asked to reflect about the first time they used the market simulator. Later in the semester, during Week 13, the students reflected again after having used the market simulator for several weeks, including for final project deliverables. The assignment prompts given to the students, within the context of the course timeline, are shown in Fig. 2.

The reflections constituted 25% of the course grade and were assessed according to the following criteria: (1) sufficiently addresses the assigned topic, (2) shows evidence of original thought and personal reflection, (3) is legible, well-written, and free of obvious grammar errors, (4) is within the range of acceptable length (300–500 words), and (5) is submitted on time. The reflection assignments in the course were due on Monday each week. The reflection assignments were posted on Wednesday after class, and students were encouraged to complete the reflections prior to the weekend to ensure class experiences were retained.

3.4.2 Final Reports

At the end of the course, the student project teams were required to submit final reports describing their design process, final design, and the success of their project. In the final report, a specific section called "lessons learned" prompted the students to reflect and discuss the overall ideas that the teams have learned from the course. This required some level of team reflection on the course, and frequently-mentioned topics in this section included teamwork, the market simulator for bringing the design to the market, and understanding the design

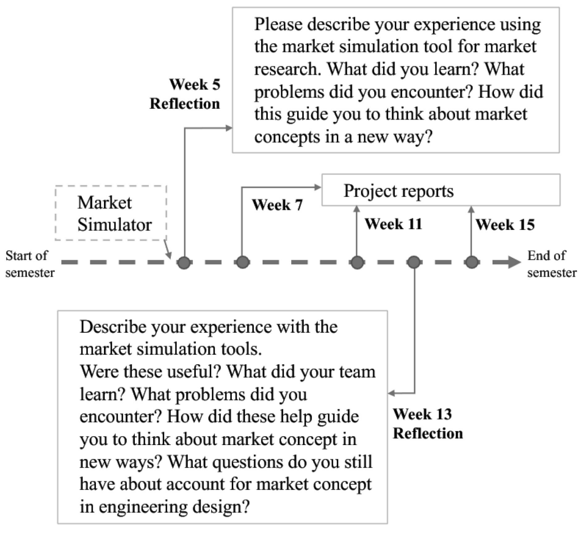

Fig. 2. Reflection activities on the use of market simulator within the course timeline.

problem before generating and choosing solutions. This section was intended to capture student perspectives about their class participation. An iterative process was applied to theming the written work. First, the primary assessor, the second author, compiled the mentioned concepts or topics along with specific excerpts from student entries into a spreadsheet for each team's final reports. Then, the topics that were common across themes were noted and consolidated. The thematic analysis steps are discussed in more details later.

3.4.3 *Post-Simulator and End-of-Course Surveys*

Two surveys were given to the students after they first used the market simulator (post-simulator) and at the end of the course (EOC) when the students had used the simulator for several weeks through their final project. The post-simulator survey focused specifically on students' experiences with the simulator, while the EOC survey focused on the students' experiences with the course overall as well as the market simulator. The surveys aimed to capture students' reflections on these topics in a structured way, and included questions about their perspectives on the value of the market simulator for learning and for improving their product designs. Combined, the two surveys included 12 prompts on a 7-point Likert scale from "strongly disagree" to "strongly agree," shown in Table 1.

3.4.4 *Analysis of Levels and Themes of Reflection*

3.4.4.1 *Levels of Reflection*

A four-category scheme for coding and assessing the level of reflection in written work was developed by Kember et al. [36]. The levels of reflection and the guidelines for categorizing written work can be seen in Table 2. This protocol had the goal of giving teachers a guideline to assess written reflections while reducing subjectivity. Kember et al. [36] noted that written work will often contain a large part of non-reflective material, but when assessing, the focus should be on the highest level of reflection present at any part of the entry. In the present study, Kember et al.'s scheme was used to analyze student reflections in determining the depth of reflection.

Table 1. Post-simulator and end-of-course (EOC) survey prompts, using 7-point Likert scale from "Strongly disagree (1)" to "Strongly agree (7)"

Prompt #	Survey	Prompt
Prompt 1	post-simulator	The market simulator helped us think about the product's price in ways that we hadn't before.
Prompt 2	post-simulator	The market simulator helped us to frame our product in the context of the competition.
Prompt 3	post-simulator	The market simulator revealed that we need to do more research on customer needs.
Prompt 4	post-simulator	The market simulator revealed that we need to do more research on the competition.
Prompt 5	post-simulator	Overall, the market simulator will contribute to a better design.
Prompt 6	EOC	My experiences in this class with the market simulator tool have contributed to my ability to design better products.
Prompt 7	EOC	My experiences in this class with the market simulator tool have contributed to my ability to analyze product designs.
Prompt 8	EOC	My experiences in this class with the market simulator tool have contributed to a better understanding of the role that market research has in successful product development.
Prompt 9	EOC	My experiences in this class with the market simulator tool have helped me to better understand the interactions between pricing strategies and design decisions.
Prompt 10	EOC	My experiences in this class with the market simulator tool have contributed to my ability to analyze the business case of a new product idea.
Prompt 11	EOC	The market simulator tool is useful in the early phases of the design process.
Prompt 12	EOC	The market simulator tool is useful in the late phases of the design process.

Table 2. Levels of reflective practice [36]

Level	Description
1: Non-reflection	The essay shows no evidence of the participant attempting to reach an understanding of the concept or theory that underpins the topic. Material has been placed into an essay without the participant thinking seriously about it, trying to interpret the material, or forming a view. Largely reproduction, with or without adaptation of the work of others.
2: Understanding	There is evidence of understanding a concept or topic. Material is confined by theory. Reliance is seen in what is in the textbook or lecture notes. The theory is not related to personal experiences, real-life applications, or practical situations.
3: Reflection	The theory is applied to practical situations. Situations encountered in practice are considered and successfully discussed what has been taught. There are personal insights that go beyond book theory.
4: Critical Reflection	There is evidence of a change in perspective over a fundamental belief of the understanding of a key concept or phenomenon. There is evidence of behavior change.

Three assessors (the first, second and third author) individually assigned levels to each of the reflections using the protocol, during which the assessors did not communicate about their assignments. After the individual assignments were completed, a meeting among the assessors was set to discuss the assignment experiences and to come to a consensus. During this meeting, the primary assessor showed each reflection in question and the level assigned by each assessor to discuss. The primary assessor led the discussion about the apparent disagreements among the level assignments. After discussing and agreeing on a level, the primary assessor took note of the new and the previous level assignment. In other words, both the originally assigned levels and the agreed-upon level for each reflection were noted for each reflection. These measures were taken to ensure inter-rater reliability [38, 39], which means that observers are rating consistently about a similar phenomenon.

3.4.4.2 Themes

A thematic analysis was also conducted to determine emergent themes in the written reflections [40]. When analyzing reflections about what makes a successful team, Hirsch and McKenna [24] measured the percentage of reflections that mentioned important themes and then compared the outcomes before and after class activities involving teamwork. The focus of comparing themes mentioned before and after students engage in new experiences shows that perspectives can change in terms of how topics are internalized and interpreted during and after having the experience. The present study also analyzed the themes found in student reflections in a similar manner. This provided an insight into what students were reflecting about as they used the market simulator and how these thoughts change throughout the course.

Reflections were qualitatively assessed by investigating and determining emergent themes. In this case study, the themes were determined by first examining ten essays by one author to find common categories of thought. Themes were initially noted by analyzing the Week 5 reflections and identifying the common topics discussed by the students. Consequently, the Week 5 and the Week 13 reflections were analyzed by documenting quotes as they corresponded with the emergent themes. These themes were then presented to the full research group to get feedback on how the themes were chosen, labeled, and defined. The group then decided to combine several themes that were similarly described as they relate to the market-related concepts introduced in the course. This resulted in a defined set of themes that emerged in each reflection assignment, as well as a data set indicating whether each student mentioned each theme.

4. Results and Findings

The findings of the analysis of reflections, final reports, and surveys are reported in this section through the assignment of levels of reflection, identified emergent themes, and data from the two surveys and the lessons learned sections of the final project reports.

4.1 Levels of Reflection

For the Weeks 5 and 13 reflections, students were generally at level 2 (understanding) and level 3 (reflection). Students had higher scores on the Week 13 reflection assignment, with a majority in the level 3 (reflection) category. Fig. 3 shows how

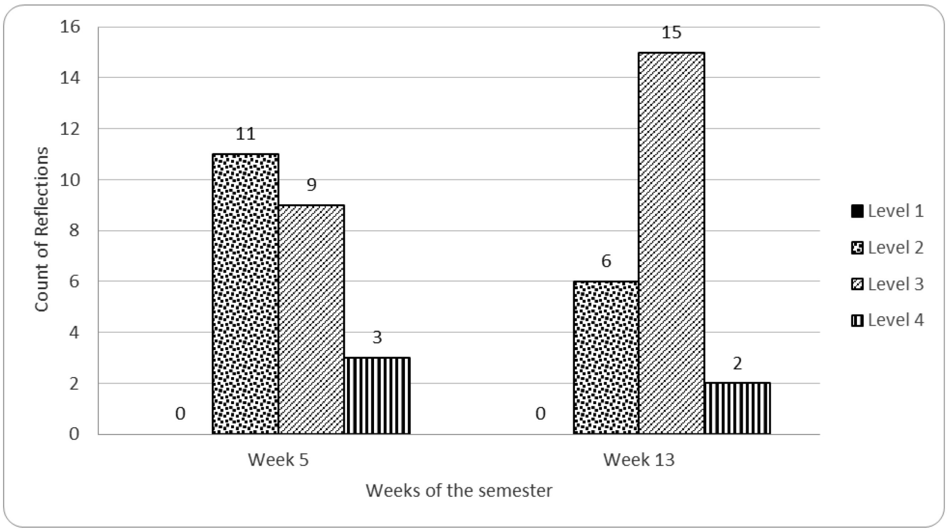

Fig. 3. Level counts for the Week 5 and Week 13 reflections.

Table 3. Emergent themes used in thematic analysis

Theme	Description
Consumers	When using the market simulator, students often commented on getting a stronger understanding of what consumers want in their product.
Competitors	The market simulator compares the student team's product to competitors' similar products, which allows teams to see how their product will compete in the market.
Pricing	The price of a product is an important attribute to determine for the market. Comparing the prices of products in the market prompts students to discuss how they might price their product.
Recyclability, environmental friendliness	Focusing on reusing products and being aware of the effects on the environment is an attribute that some students discussed, considering consumers' interests in today's world.
Future applications	Some students noted how the market simulator could be helpful later in their careers or their senior design project. Students thought the simulator was important to the design process and they would like to implement the simulator in future projects.
Valuable	This notes when students felt the market simulators were valuable to their project.
Visual representation appreciation	The market simulators give a visual representation to help students see how the market affects their product. Some students enjoyed the simulator's visual presentation.
Attribute estimation difficulties	To run the simulations, all of the attributes must be quantified even if they are qualitative measures for the product. Several teams had difficulty estimating attributes if they were unable to fully characterize their products or if they had to assess the competitors.
General difficulties	While using the market simulators, some students noted what made their experience more difficult.

Table 4. The occurrences of mentioned themes in the scheduled weeks of reflection

Theme	Week 5	Week 13	% Change	p-value
Market Simulator Valuable	87.0%	69.6%	–17.4%	0.162
Comparing to Competitors	73.9%	47.8%	–26.1%	0.030*
Understanding Consumers	52.2%	65.2%	13.0%	0.213
Difficult Estimating Attributes	52.2%	30.4%	–21.7%	0.135
Commenting on Difficulties	43.5%	60.9%	17.4%	0.213
Future Applications	8.7%	17.4%	8.7%	0.426
Enjoys Visual Representation	21.7%	17.4%	–4.3%	0.714
Pricing	30.4%	30.4%	0%	1
Recyclability, environmental friendliness	13.0%	8.7%	–4.3%	0.575

* Statistically significant.

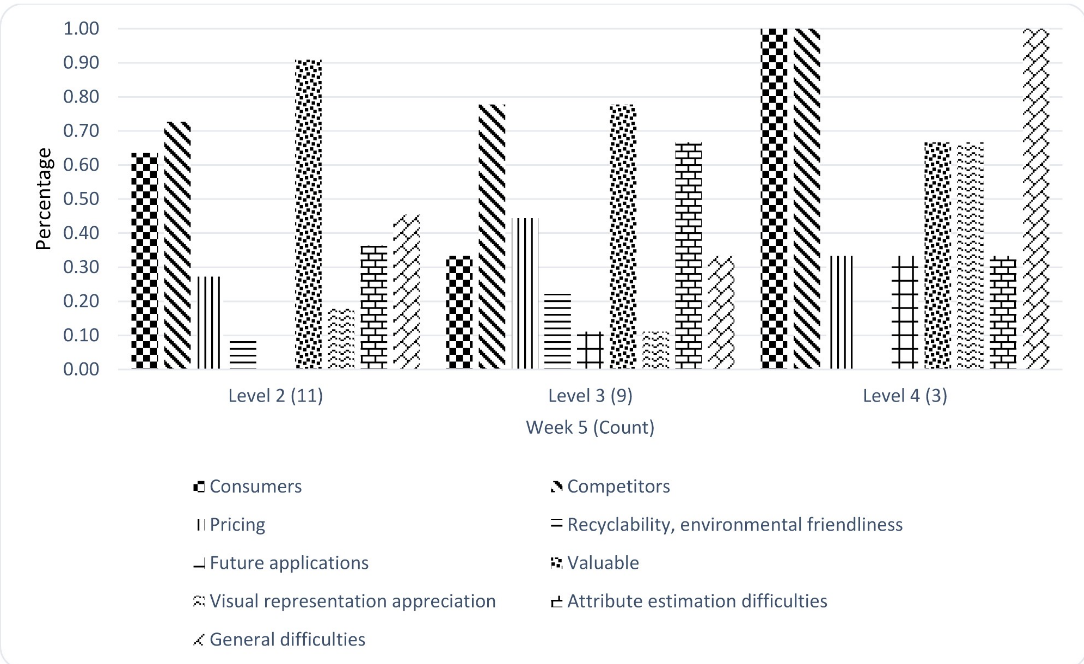

Fig. 4. Percentage of themes mentioned in Week 5 reflections categorized by level.

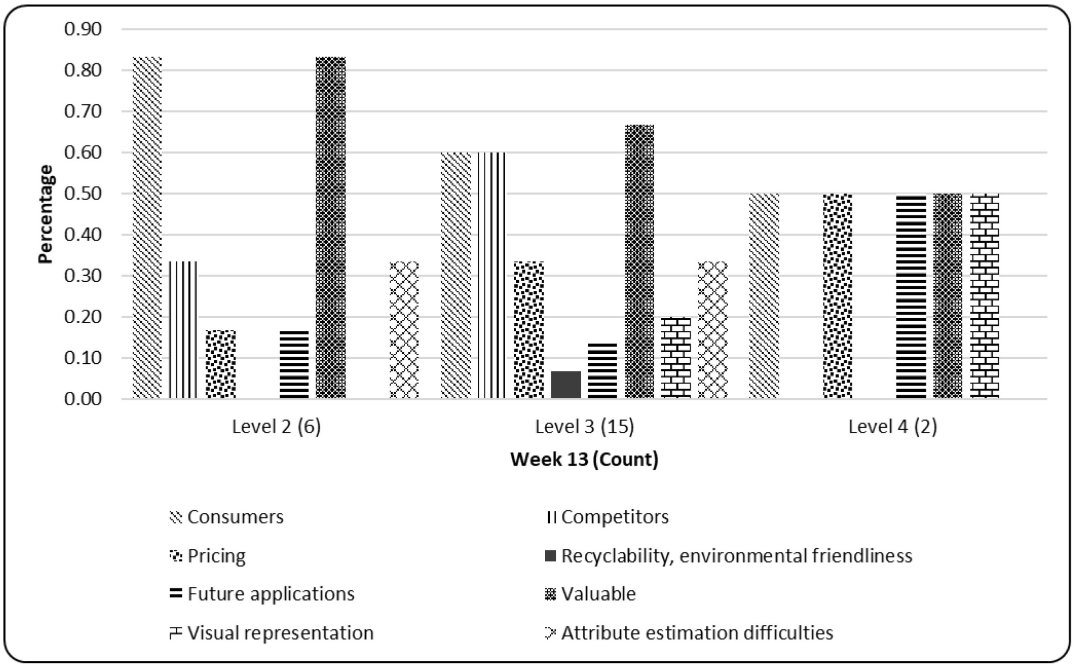

Fig. 5. Percentage of themes mentioned in Week 13 reflections categorized by level.

improvement may be observed between Week 3 and Week 13 in terms of the students' level of reflection.

4.2 Themes

The descriptions of all themes used when analyzing the students' reflection entries, resulting from the iterative process described in Section 3.4.4, are provided in Table 3. These themes emerged multiple times across the written work and were subsequently used in the thematic analysis as they relate to the design and market concepts taught in the course.

Table 4 shows the difference between the occurrences of mentioned themes in the scheduled weeks of reflection. With the four-category scheme and emergent themes consequently identified, the following changes were observed between Week 5 and Week 13 reflections. The Comparing to Competitors theme was the only statistically significant (significant decrease) theme among the mentioned themes, see Table 4. In Week 5, the students focused more prominently on the themes Market Simulator Valuable and Difficult Estimating Attributes. Whereas in Week 13, they were more interested in Understanding Customers and Commenting on Difficulties.

Figs. 4 and 5 show the percentage of reflections

Table 5. *Lessons learned* takeaway descriptions

Takeaway	Description
Time management	Students learn time management by working together to meet the assignment deadlines without procrastinating. The teams were responsible for managing their own time to meet the deadlines of the course.
Focus on the problem before the solution	While looking back on their work, some teams took note that defining and scoping their problem better in the beginning is an important step to developing a better solution. Teams felt that they tend to design their product too quickly without researching and defining the problem.
Accountability of all team members	When working in a team to meet deadlines, dividing up work and team members' accountability are important. Some final reports mentioned that the team leader should not be responsible for completing all the work but instead properly delegate work, making the team members hold themselves and one another accountable.
Future/real-world applications	The skills learned in Design VI apply to future projects that students will complete in school and in their careers. Many groups noted skills that will be applicable to their senior design project, which most of the students plan to begin in the ensuing semester.
Comparing Design VI to previous courses	Design VI exposes students to many different skills not used in previous design courses, and students seemed to appreciate the new skills, methods, and tools learned. The skills that the teams acknowledged include techniques for understanding the market, consumers, profitability, sustainability, and business aspects.
Discuss market simulator	After using the simulator and applying it to their project, teams discussed the market simulator in a way that they found value and utility to the design process as a whole.

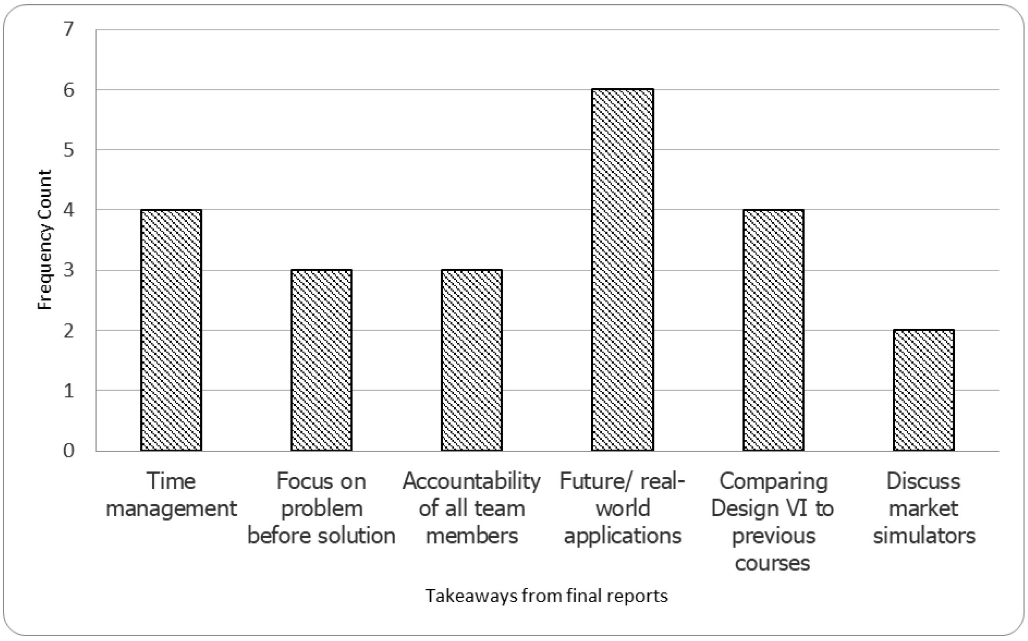

Fig. 6. Frequency count of takeaways in the lessons learned section of the final report.

Table 6. Average and standard deviation of survey prompt response values

Prompt #	1	2	3	4	5	6	7	8	9	10	11	12
Survey	Post-Simulator (5.32 avg.)					EOC (5.03 avg.)						
Avg. Response	5.00	5.21	5.43	5.34	5.61	4.82	4.95	5.39	5.43	4.95	4.26	5.47
Std. Deviation	1.41	1.47	1.82	1.80	1.56	1.40	1.26	1.30	1.20	1.36	1.86	1.24

that mentioned each theme, categorized by level of reflection for Week 5 and Week 13, respectively. The figures show there were marked decreases in level 2 and 4 reflections between Week 5 and 13 while there was an increase in level 3 reflections.

4.3 Final Reports – Lessons Learned

After analyzing the lessons learned section of the final reports, a summary of the commonly identified takeaways of the student teams is shown in Table 5.

The occurrences of the takeaway topics can be

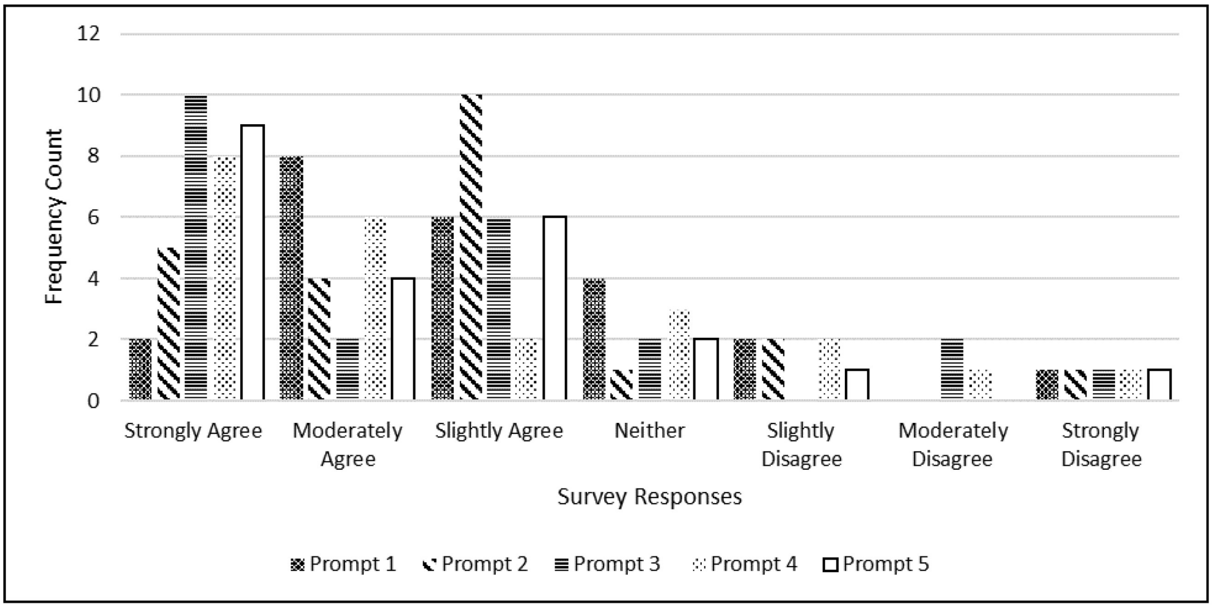

Fig. 7. Frequency count of post simulator survey responses.

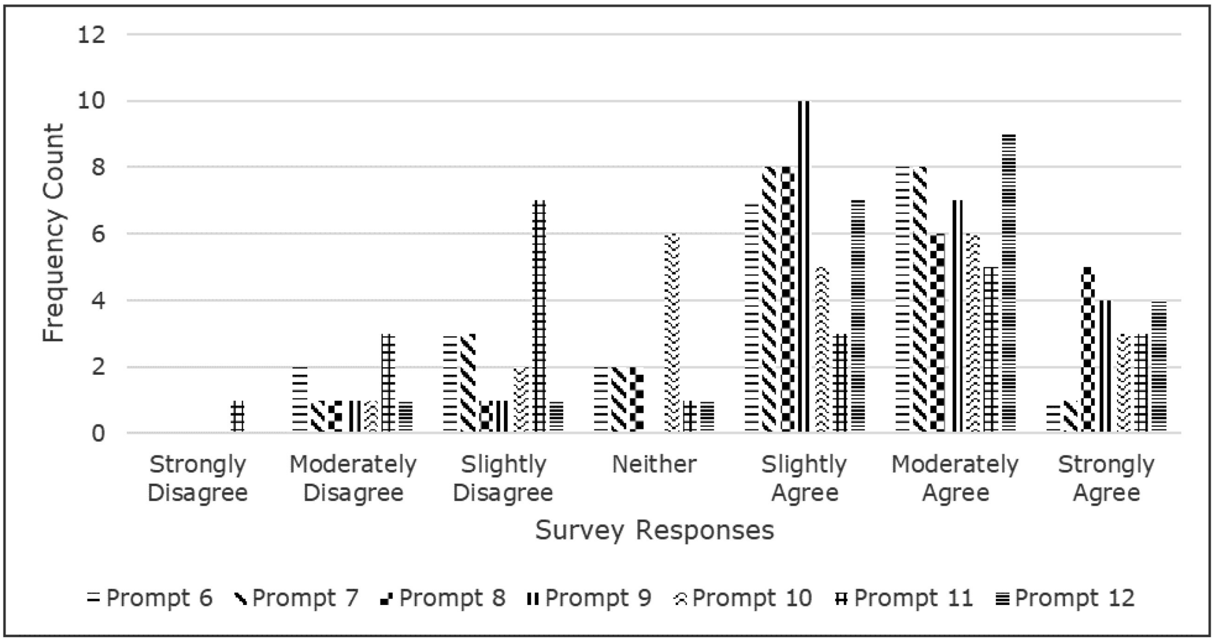

Fig. 8. Frequency count of end-of-course survey responses.

seen in Fig. 6. In the reports, 6 out of 7 teams discussed how they can use the skills they learned in the future for either their senior design project or in their careers. In addition, 4 of the 7 teams discussed the importance of time management and compared their experience in this particular design course to previous design courses.

4.4 Post Market Simulator and End of Course Surveys

The surveys were intended to capture whether students thought the market simulator helped them develop a better design. The prompts used in the post-simulator and end-of-course surveys can be seen in Table 1 under Section 3.4.3. The students responded to the prompts on a Likert scale of 1 to 7 on how strongly they agree or disagree with the statement. The distribution of responses for the two surveys can be seen in Figs. 7 and 8, while the summary statistics of the responses are shown in Table 6.

Based on the survey responses, none of the results averaged out to a level of disagreement with the prompt statement, which means the overall results were on the "Agree" side of the scale. The lowest overall response was observed in prompt 11 (*The market simulator tool is useful in the early phases of the design process*) at an average of 4.26, sitting in the neutral range. Prompt 5 (*Overall, the market simulator will contribute to a better design*) got the most positive response rate with an average of 5.61, which sits in the "Moderately Agree" range.

The variations in the post-simulator survey were slightly higher with an average standard deviation of 1.50 versus 1.37 in the EOC survey. However, the prompt with the highest standard deviation is prompt 11 at 1.86. The prompt with the smallest standard deviation is prompt 9 at 1.20. This means that the post-simulator survey had a slightly wider dispersion than the EOC survey when it comes to student responses to the prompts.

5. Discussion

In this study we sought to answer the following questions: (1) What key themes do students identify through reflection of their use of the market simulator? (2) How do students' engagement and effort correspond with these key themes?

The students' responses to the reflection prompt yielded nine common themes across the two weeks of reflection assessed. The findings highlight the importance of understanding the market when designing a product, as students acknowledged how the market simulator helped them get through their project in the Design VI course. Student reflections noted the value of the market simulator and how it allowed them to get insight into how to make their product successful, particularly by thinking more deeply about consumers, competitors, pricing, and environmental friendliness. Students felt that the market simulator was valuable to the design process as evidenced by their indication that they intend to use the market simulations or models in their future projects and careers. These findings are in congruence with the principles associated with reflective practice in that students were able to engage in critical thinking about how the course activities, centered around the use of the market simulator, could be useful as they complete the other courses in the Design Spine.

Between the week 5 and week 13 reflections, we did observe a decrease in mention of the value of the market simulator and an increase in acknowledging difficulties, which may show how students' response to the market simulator changes as they reflected again, use the simulator as part of a graded assignment, and become aware of the complexity of the design process as it relates to market impacts. However, we did see small increases in students' understanding of consumers and their needs and how the market simulator could be applied to future applications. Similarly, when they were asked if the market simulator contributed to a better design, some students responded that they strongly agree. When responding to competitors and consumers, students' reflections showed that this allowed them to understand what is important in their design and what specific attributes to focus on. As students used the market simulator more often, more reflections emerged regarding the difficulties in estimating attributes as students use the market simulator with more components to consider. Students also highlighted the importance of price and effects on the environment in their reflection, factors that most industries and stakeholders find important [41].

Looking at how students engaged with the reflection task more broadly, we saw an increase in level 3 reflections between Week 5 and Week 13 (from 9 to 15) and a decrease in level 2 reflections (from 11 to 6). Recall from Table 2 that level 2 reflections indicate evidence of understanding a topic while level 3 reflections indicate the concept is being applied to practical situations. This finding aligns with work done by Turns and colleagues [8] that found when students were able to relate a concept to a personal experience or the concept was thought to build on something they had previously encountered whether in the class or another context, their level of understanding increased. This is also supported by Walther et al. [42] who posit that using guided deliberate reflection tasks hold significant benefits for students in that within the scope of a course they can increase their understanding of concepts by reflecting on their engagement with course material.

The key takeaways in the teams' final reports showed parallels with the course objectives. The course objectives include students facilitating their teams, learning how to work on a team, designing with an impact in today's society, and designing a product from concept to the market. These resemblances illustrate how students' overall learning aligned with the learning outcomes of the class, especially in terms of developing the skills desired for engineers in the 21st century [4]. Our findings provide empirical evidence of significant aspects of reflection: self-knowledge, relating experience to knowledge, self-reflection, and self-regulation of the learning processes [43]. These are critical factors in practicing the professional skills that are required in engineering design.

6. Limitations and Opportunities for Future Work

This work, like all research projects, has its own set of limitations. Firstly, we acknowledge that we only looked at two weeks set of reflections even though we collected reflection responses from the students over the course of the semester. While we used the weeks when the market simulator was explicitly mentioned and or used in the course it is possible that the students reflected on the simulator in relation to other course topics. In a current extension of this study we are analyzing all the reflection responses the students submitted.

As mentioned earlier in the results and discussion section, we saw a marked decrease on the students' perception of how valuable the market simulator is and an increased in their perception of difficulty using the tool. A more detailed exploration of the underlying reasons for these decreases would provide more information to researchers about students' overall appreciation for the simulator as well as what steps could be taken by the instructor to reduce difficulties students encountered. To better understand the students' perspective, we designed focus groups to be performed with students after the end of course that have been performed as of now to uncover the challenges students faced.

To build on these findings, future studies may seek to gauge students' knowledge of the market before the beginning of the course. This would help understand how prior knowledge evolves into learnings about the dynamics of the design and the market throughout the course, enabling students to change their view of design and decision-making on the use of the market simulator in their design process after going through the course. This study further establishes relevance as it is a stepping stone to designing instructional strategies that make students reflect at a higher level to improve students' reflective practices on course materials.

7. Conclusions

This study specifically aimed to explore what key themes the market simulator prompts students to think more deeply about, how the students' depth of reflection correlate to the themes identified during reflection, and how student appreciation for and enjoyment with the market simulator correlate with learning, as measured by the depth of reflection, course grades, and lessons learned in the Design VI course. To address these goals, we utilize student reflection entries and final project reports as tools to understand students' overall learning of the use of the market simulator toward design processes in an engineering design course.

Significant insights were gained from this study in terms of improving an engineering design course. First, reflective practice is an effective instructional strategy for students to develop holistic self-regulated learning and professional skills. Studies of reflection activities in the classroom all indicate their benefits in helping students engage with content in a meaningful and lasting way. Our study has also demonstrated how the use of reflection activities in design courses can assist students to think about continuity between concepts in a course and how one course may be connected to another. This work holds several implications for educators and practitioners who are keen in using reflection activities in their courses. With the analysis of levels of reflection on the use of the market simulator, themes that pertain to the concepts in the design course emerged as potential indicators of how students interpreted their engagement with the tool. These initial understandings of the role of reflection in the design process could be further developed and explored to highlight the critical role reflection can play in the design process as a whole. Second, team reports on "lessons learned" signify that reflective practice is a viable learning strategy that can lead to more in-depth engagement with the course material over an extended period of time. Lastly, the frequent reflective practice helped students gain an appreciation of how they are able to explore different aspects of the design process, especially the considerations and implications of their design to the market and how the market drives their design processes, and how students become cognizant of the significant attributes and the evolution of their own thinking into achieving success of their design.

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