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DO STUDENTS WANT TO DISSECT? A SURVEY OF STUDENT OPINIONS ON THE USE OF PRODUCT DISSECTION IN THE CLASSROOM

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Abstract

Product dissection has the ability to create an engaging and active learning environment for engineering students. The purpose of this paper was to further investigate students' perceptions on product dissection in the classroom. This paper was developed to provide an examination of the usefulness of product dissection for idea generation and how product dissection modules might aid in students' understanding of the module. The findings of this paper conclude that students felt that the product dissection module was useful, valuable, and enjoyable and that students had a positive sentiment towards the designed aspects of the dissection module. Through the use of content analysis, areas for improvement in these modules are identified.

INTRODUCTION

Benjamin Franklin once said, "Tell me and I forget. Teach me and I remember. Involve me and I learn". Franklin exemplifies the importance of hands on learning for not only remembering, but for utilizing all five of the higher levels of cognitive processes from Bloom's taxonomy [1, 2] including *understanding, applying, analyzing, evaluating, and creating* [3]. In fact, requirements set forth by the Accreditation Board for Engineering and Technology (ABET) emphasize design and the "development of student creativity…"[4] (page 18). This focus on creativity from ABET along with a pivot towards experiential learning in engineering classrooms have set the standards for engineering education [5-7]. Previous research was conducted to develop a sustainable solution to help engineering students understand the requirements ABET set forth. Specifically, this research focuses on helping students "understand the global, economic, environmental, and social context and impact of engineering solutions" [8]. Thus, this ABET requirement emphasizes the importance of keeping engineering students engaged and creative in the classroom; both of these goals can be achieved through experiential learning. One way that educators can provide experiential learning is through the development of instructional material that enable students to create[9].

One such experiential learning activity is product dissection, which has been a staple of engineering education to encourage understanding of how products work and to promote creativity during the engineering design process [10]. Because of the prominence of product dissection in engineering education, extensive research has been conducted by our research group over the past 3 years. This research aimed at understanding how variations in product dissection conditions impacted learning and creativity with engineering students [10-16]. Specifically, research found that virtual dissection is just as effective as physical product dissection for conceptual understanding [16, 17]. Previous research has also found that product dissection helped students focus on both form and function when designing a new product [18]. Specifically, this study found that students who did not complete dissection focused only on form when designing a new product while students who did dissect exhibited higher creativity levels. Other research has also shown that dissecting a larger variety of products can help teams of students explore a larger solution space [14]. This research is important for understanding how product dissection can affect conceptual understanding and creativity but what we do not know is how this experiential learning activity will impact student motivation to complete product dissection. Understanding the impact is important because motivation is an important factor in learning; it is what makes humans curious and with a readiness to learn [19]. The results from this experiential learning activity will give insight into students' intrinsic motivation to learn.

To put this research into practice, product dissection modules were created to understand the impact on student learning in engineering education. Further understanding student learning is important because it can help shape how engineering education is designed in the future. The product dissection module presented in this paper serves to engage students in understanding, application, evaluation and creation by guiding students through a product dissection activity. The goal of this paper is to identify if students are intrinsically motivated to complete dissection and if the content of the dissection activity developed for the classroom is perceived to be useful by the students.

RELATED WORK

In order to lay a groundwork for the current study, background literature was surveyed on product dissection, learning, and motivation in engineering education.

Product Dissection Modules in Design Classrooms

Product dissection has been heavily researched in the past few years for its ability to help designers generate more novel ideas for a new product [10, 11, 13-15]. By fully taking apart a product, through product dissection, students become more aware of how products are engineered and operate [12]. Product dissection can be used to develop an active learning classroom environment and to help students question, observe, and actively understand how a product works [20]. Research conducted with engineering students concludes that hands on activities, such as product dissection, encourage creativity and exhibit real world application of engineering principles [21]. Creativity is an essential part of the design process and is necessary in order to translate innovative ideas into actual products [22]. Creative ideas are desired in the concept generation phase and are considered an important part of the design process [23]. Product dissection has been proven to result in more creatives ideas during the idea generation phase because it helps to facilitate participant exploration of a larger design space [18].

Based on this prior research, product dissection modules were created for the purposes of this study. These modules incorporate past findings about the usefulness of product dissection on creativity and idea generation. The active learning approach is incorporated into these product dissection modules to further engage students and to investigate the benefits of implementing modules in engineering education. For the modules used in this study, virtual product dissection was used instead of physical dissection. Because physical product dissection is expensive, virtual product dissection has gained traction as a cheaper and more accessible option in engineering classrooms [11, 12, 17]. Virtual product dissection does not provide the same hands-on (tactile) experience as physical product dissection but it can still be used as an effective tool in the classroom to increase students' understanding of engineering design principles [17]. One study looked at combining virtual and physical dissection via "cyber-enhanced product dissection" and found that product dissection was beneficial regardless of the method used (virtual, physical or cyber-enhanced) [24]. Previous research has also shown that virtual dissection is more efficient than physical product dissection yet still provides the same learning benefits [15]. Another study found that virtual dissection can be better than physical dissection for increasing student creativity [10, 21].

In this module, a variety of products were made available for students to choose to virtually dissect. A previous study shows that dissecting a variety of products allows participants to explore a larger solution space [14]. In addition, previous research shows that product dissection can positively affect student creativity, regardless of the type of product dissected [10, 25]. Therefore, students were able to choose, from a selection of 8 different products, which one they wanted to dissect. Finally, a worksheet was used in the modules to help guide students through virtual product dissection. This worksheet did not require students to generate a Bill of Materials (BOM) or Functional Layout Diagram (FLD) since previous research found that neither of these further enhance students' conceptual understanding and learning [26]. To replace the FLD and BOM, new instructional materials were developed to provide more guidance during product dissection.

The product dissection modules created for this study are important because they use previous research on the effectiveness of product dissection for learning and creativity to support the creation of educational materials for use in the classroom. While their creation is founded in quantitative research, this does not guarantee that they will be received positively in an engineering classroom. Therefore, it is important to understand student perceptions of the activity and student motivation to complete product dissection.

Learning and Motivation in Engineering Education

Active learning involves students rather than just having them listen [27] and can help students develop higher levels of analytical skills [28]. Bloom's taxonomy also underscores the importance of learning through use of higher-level cognitive processes such as *understanding, applying, analyzing, evaluating, and creating* [1-3]. In order to provide students with active learning environments, the "flipped classroom" approach, which replaces traditional lecture style teaching with active in-class tasks, has been applied [29]. This experiential, problem-based learning can help to keep students engaged and motivated in the classroom[30].

In education, we can provide students with these experiential learning experiences so that they can be motivated to perform activities, be creative, and subsequently learn. Past research has also found that faculty motivation can play a role in how motivated students are to make choices in the classroom[31].To be motivated means to be moved to do something [19]. Motivation is what energizes and guides a person's behavior towards a particular outcome [32]. The most basic distinction between types of motivation is between intrinsic motivation and extrinsic motivation [19]. Intrinsic motivation refers to an individual doing something because it is interesting or enjoyable while extrinsic motivation refers to doing something because it leads to a certain outcome. It was first acknowledged in experimental studies of animal behavior in which it was discovered that many organisms engage in exploratory and curiosity-driven behaviors even without reinforcement or reward [33]. In humans, intrinsic motivation is prevalent from birth onwards; humans are inquisitive and curious in nature and have a readiness to learn [19] .

Intrinsic motivation has emerged as an important phenomena for education because it can be catalyzed by institutional or teacher practices [19]. Academic intrinsic motivation has been found to be significantly correlated with the academic achievements of students [34]. In education, students can be motivated by extrinsic rewards and incentives [35]. In a study performed by Deci, Koestner, & Ryan, it was determined that tangible rewards do have a significant effect on the intrinsic motivation of students [35]. In a different study performed by Skinner, it was discovered that all behaviors are motivated by some sort of reward [36]. Another study looked at the "flipped classroom" approach which replaces traditional lecture style teaching with active in-class tasks [29]. Abeysekera and Dawson make the argument that flipped approaches might improve student motivation in the classroom.

In research, the Intrinsic Motivation Inventory (IMI) is used as a measurement tool used to assess the participants subjective experience related to a specific activity. McAuley, Duncan, and Tammen did a study to assess the validity of the Intrinsic Motivation Inventory and found strong support for its validity [37]. This instrument assesses participants' enjoyment, perceived competence, effort, value, usefulness, pressure, and perceived choice [19].

Research Objectives

The purpose of the current study was to understand student perceptions of the product dissection module developed for use in engineering classrooms. Particularly, our study was developed to answer how the design task and instructional materials provided during dissection activities impact student intrinsic motivation and sentiment towards components of the dissection module. Specifically, our hypotheses were as follows:

- Students will have high levels of intrinsic motivation to complete dissection, since in-class activities can help to improve student motivation in the classroom [29], but the different instructional materials and design tasks will impact this level of intrinsic motivation since the task may be more relatable and the instructional materials have different levels of information.

- Students will find all aspects of the product dissection module useful, regardless of their condition, since the module was developed based on evidence from quantitative research conducted over the last 3-4 years [12, 15, 20, 21].

- Students will be able to effectively use product dissection to help with idea generation and choose appropriate products to dissect based on the instructional materials. The instructional material provided will impact how students are able to connect product dissection with idea generation.

METHODOLOGY

To answer these research questions, product dissection modules were implemented in two sections of a first-year engineering design course. The study had a total of 56 student participants. This section summarizes the methodological approach taken in this study.

Participants

Participants were recruited from a first-year introduction to engineering design course at a large northeastern university. Students were recruited from 2 of the 24 sections offered per semester. In total, 56 students (38 males and 18 females) agreed to participate in the design study.

Experimental Design

The study was a 2 (*design task - Toy or Alarm)* x 2 (*instructional material - Worksheet A or B)* factorial design, with participants randomly assigned to a condition before the study.

Design Task: Students were presented with one of two design tasks to complete during the module. The first group (28 students), was given the water toy design task: *"Design an innovative water toy for use by kids ages 4-6. The toy must be safe to use, fun, and novel."* The second group (28 students) was given the alarm clock design task: *"Design an innovative alarm clock for use by people who have a hard time waking up to traditional alarms. The alarm clock must be safe to use and novel"* These two groups are denoted as Toy and Alarm, respectively throughout the remainder of the paper.

Instructional Material (Worksheet): All students were given a worksheet to complete as part of their dissection module. Students were broken into teams of 3-4 and then each member of the team was given a worksheet to support their dissection. Within the 3-4 student team, all students had the same worksheet. The first group (30 students) were given worksheet A which focused on drawing and writing out the functions of the dissected product. The second group (26 students) were given worksheet B which focused on application to the design problem in addition to the functions focused on in worksheet A. These worksheets can be found at www.engr.psu.edu/productdissection.

Procedure

At the start of the experiment, an overview of the study was provided, and implied consent was obtained. Participants started by completing a pre-survey where they were asked to complete a 3 question creative self-efficacy survey developed by Tierney and Farmer [38]. Next, students participated in a discussion about creativity in engineering design and watched a creativity video developed by Penn State's School of Engineering Design Technology and Professional Programs (SEDTAPP). Students then completed an alternate use test [39] creativity exercise.

Participants were then randomly assigned to their design task condition in the 2-design task x 2 instructional material factorial design study (see Experimental Design section for more details). After receiving their design task, the participants were given 10 minutes to individually generate as many ideas as they could. After this first round of idea generation, the students were instructed to watch a video on what product dissection is and how to use it. Next, participants were separated into groups of 4 and assigned to their instructional material condition where they were given worksheet A or B (found at www.engr.psu.edu/productdissection). As a team, students chose which products to individually dissect using the instructions in their worksheet: "Each teammate should dissect a *different* product." Students chose one product from a collection of eight products found on the product dissection website (www.engr.psu.edu/productdissection). Products on the website included a milk frother, tape dispenser, french press, cordless drill, hand mixer, toothbrush, spray bottle, and nerf gun. Before completing the product, dissection activity students watched a short video on how to use the virtual dissection software (SolidWorks eDrawings).

Participants were given 15 minutes to virtually dissect the product that they chose from the website using SolidWorks eDrawings provided to them on laboratory computers. Students individually dissected their products using their worksheet to guide them through the process of dissection. Both worksheets asked participants to functionally describe and visually sketch the power supply, primary motion, energy flow and form & outer body of the product they chose to dissect. Worksheet B, also asked the participants to provide an application opportunity for each of these categories, specifically asking "how can this be applied to my design task (toy/alarm)".

After the dissection, the students were given 10 minutes to generate as many more ideas as they could for their specific design task- either to design an alarm clock or a water toy. Next, students were given a post-survey where they responded to 7-point Likert type survey about their intrinsic motivation to complete the dissection module [40], Likert type scale questions on their perceptions about the different aspects of the module, and open response questions about their experiences during dissection (see www.engr.psu.edu/productdissection for the scale and a full list of questions).

Metrics and Analysis Tools

In order to understand student perceptions of the dissection module, several metrics were used to understand creative self-efficacy and intrinsic motivation to complete dissection. In addition to these metrics, content analysis tools were used. These metrics and tools are described in detail in the following section

Creative Self-Efficacy (CSE): Creative self-efficacy is the "belief one has the ability to produce creative outcomes" [41]. This scale consists of 3 questions such as "I have confidence in my ability to solve problems creatively" and has been validated in prior research.

Intrinsic Motivation Inventory (IMI): The Intrinsic Motivation Inventory (IMI) instrument assesses participants interest/enjoyment, perceived ability to complete the module effectively, effort, value, and usefulness [19]. In this study, we utilized three different subscales of the IMI; "Useful", "Value", and "Enjoyment". Questions in our post dissection survey were classified as "useful" (#1, 2), "value" (#3,4,5), and "enjoyment" (#6,8,11,13), Questions using the IMI were presented using a Likert type scale of 1-7. For each subscale of the IMI (useful, value, enjoyment) the questions were added together and normalized to a scale of 1-7 (averaged).

Product Dissection Module Survey: In order to determine the usefulness of different portions of the product dissection module, questions were presented to participants to gauge usability using a 7-point Likert type scale. Questions relating to the usefulness of the module can be found at www.engr.psu.edu/productdissection (questions 7, 9, 10, 12, 13, 14, 15)

Content Analysis:

Content analysis was performed on the open-response questions given to students in the post survey. These questions asked students about the usefulness of the module and what they might change about it in the future. Analyzing these questions gave insight into why students chose their product to dissect and how useful that product was for idea generation. The open- response questions asked on the post-survey can be found at www.engr.psu.edu/productdissection (questions #16,17,18). Each of these questions was coded separately using NVivo Pro 12. Data was coded into categories using deductive content analysis [42] to understand which aspects of the product dissection module students found to be useful and to gather recommendations for future versions of the module.

RESULTS

Before answering our research questions, it was necessary to determine if there were any differences between the two class sections used in this study. In order to test for these class differences, a one-way ANOVA was computed with "creative self-efficacy" as the dependent variable and class section as the independent variable. Prior to analysis, assumptions were checked. Specifically, analysis of a box-and-whisker plot, revealed that participants 21, 43, and 49 were considered outliers. The one-way ANOVA was conducted both with and without the outliers to determine their impact on the results. Since there was no impact on the significance of results, analyses were presented with the full data set, including the outliers. Normality of both data sets, with and without outliers, was also tested using the Shapiro-Wilk test. In both cases, normality was violated ($p<0.05$). Due to violations in normality, bootstrapping was used to mitigate the effects of these violations. In SPSS, bootstrapping tests the stability of the

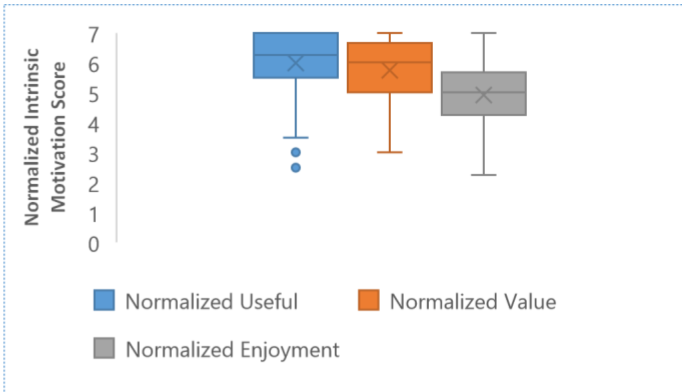

FIGURE 1: INTRINSIC MOTIVATION SCORES

data. It estimates the sampling distribution of an estimator by resampling with replacement from the original data. This process is completed by enabling bootstrapping in the ANOVA dialog box. Finally, Levine's Test for Equality of Variances revealed that the assumption of homogeneity of variances were met for overall creative self-efficacy scores. The results of the one-way ANOVA showed there was not a significant difference between the two class sections, $F(1,54) = 0.58$, $p=0.810$, partial $\eta^2=0.001$. Because of this result, class sections were considered as one population throughout the remainder of the analysis. The remainder of this section outlines the results with reference to our hypotheses using SPSS v. 25.

Intrinsic Motivation

Our first hypothesis was that students would be intrinsically motivated to perform product dissection and but that the design task and the instructional material could impact this level of motivation. In order to understand if the students were intrinsically motivated to complete the dissection module, Wilcoxson Signed Rank tests were used to compare IMI subscale values (See metrics for details) to the hypothesized median of 4 (the midpoint of the scale). The results showed that the students found dissection to be valuable ($p < 0005$, Median = 6), useful ($p < 0.005$, Median = 6), and enjoyable ($p < 0.005$, Median = 5), see Figure 1. These results indicate that students were intrinsically motivated to complete the dissection module regardless of condition, finding the module valuable, useful, and enjoyable.

In order to understand if the condition (design task or instructional material) impacted the level of intrinsic motivation that students had for completing dissection, a two-way ANOVA was computed for each IMI subscale factor. For each calculation, the IMI subscale value served as the dependent variable while the design task (toy or alarm) and instructional material (Worksheet A or B) were the two independent variables. Assumptions were checked prior to analysis of the intrinsic motivation factors including assumptions of normality, homogeneity of variances, and outliers. Because the data violated the assumption of normality bootstrapping was used to mitigate the effects of these violations. In addition, because several outliers were identified, analyses were performed with and without outliers. Since there was no impact on the significance of results, analysis is presented with the full data set, including the outliers.

The results of the three ANOVAs revealed a statistically significant main effect on value for the design task, with students who were tasked with designing a water toy (mean = 6.04, SD = 0.86) finding the module was considered more valuable for those participants who designed an alarm clock (mean = 5.53, SD = 1.02). There were no other significant main effects or interaction effects. These results indicate that students found dissection to be useful, valuable, and enjoyable in all of the different conditions, but show that the students' perceived value of the module is impacted by the design task they are presented with.

Dissection Module Survey

Our second hypothesis was that students would find all aspects of the product dissection module useful, regardless of their condition (design task or instructional materials). In order to understand if students found the dissection activities useful a Wilcoxson Signed Rank tests were used to compare student response to the hypothesized median of 4 (the midpoint of the scale). The results showed that the students found all of the components tested to be useful, see Table 1.

In order to understand if the condition (design task or instructional material) impacted student perceptions of the usefulness of the dissection module, a two-way ANOVA was computed for all product dissection module survey questions (see metrics for details). For each calculation, the module question was the dependent variable while "Task" and "Worksheet" were the two fixed factors. Assumptions were checked prior to analysis of the usefulness of other aspects of the module, including assumptions of normality, homogeneity of variances, and outliers. Because the data violated the assumption of normality, the analysis was conducted using bootstrapping in order to mitigate the effects of these violations. In addition, because several outliers were identified, the analyses were performed both with and without outliers. Since there was no impact on the significance of results with the outliers, the analysis is presented with the full data set, including the outliers. The results of the ANOVAs did not reveal any significant differences between the two different dissection activities (Worksheet A or B) nor the two different design tasks (toy or alarm). The results from the ANOVAs can be found in Table 2. These results indicate that the students

TABLE 1: RESULTS FROM WILCOXSON SIGNED RANK TES

	Useful	Value	Enjoyment	I had enough time to complete my dissection activity	I was able to draw inspiration from the
Median	6	6	5	6	5
p-value	-	-	-	0	0.02

TABLE 2: TWO-WAY ANOVA ANALYSIS

	I had enough time to complete my dissection activity	I was able to draw inspiration from the product I dissected during idea generation	The product dissection video helped me understand how to use product dissection during idea generation	The product dissection instructions helped my team choose appropriate products to dissect	Sketching different parts of the product helped me to draw inspiration from the product during idea generation	Describing different parts of the product helped me to draw inspiration from the product during idea generation
F (1,52): Handout	.005	1.190	.538	.011	.581	.1.152
F (1,52): Task	.081	.146	.306	.168	.939	1.237
p(Handout)	0.946	.280	.467	.916	.449	.288
p(Task)	0.777	.704	.582	.683	.337	.271
partial η^2 (Handout)	.000	.022	.010	.000	.011	.022
partial η^2 (Task)	.002	.003	.006	.003	.018	.023

found that there was enough time to complete the module and that the instructional material was helpful to this completion.

Student Choices in the Dissection Module

Our third hypothesis was that students will be able to effectively use product dissection to help with idea generation and choose appropriate products to dissect based on the instructional materials, but that the instructional material condition will impact this ability.

In order to understand if students were able to use the materials effectively, content analysis was performed on the three post-survey open response questions given to all students. Through the first question, "Why did you pick the product you chose to dissect?", we sought to understand students' motivation behind their chosen product. Through this content analysis, it was determined that participants chose their product because of familiarity/prior experience, the product seemed interesting/fun, they wanted to learn more about it, and to help with idea generation, see Figure 2. A total of 20 participants chose their product because of familiarity with the product or "prior experience". While the intended goal was for students to pick their product so it would help them generate ideas later on, only 1 participant said that they picked their product to help with idea generation. On the contrary, 14 participants picked their product out of a desire to learn more and 17 participants picked their product because it seemed interesting. One participant noted, "I own a hand mixer and want to see how it works" (participant #56). This shows that students are interested in learning more about how a product works. For example, one participant mentioned "I was always interested in the mechanics of a white out dispenser" (participant #6). These results indicate that student curiosity and their prior experiences may be taking priority in what product they are choosing to dissect.

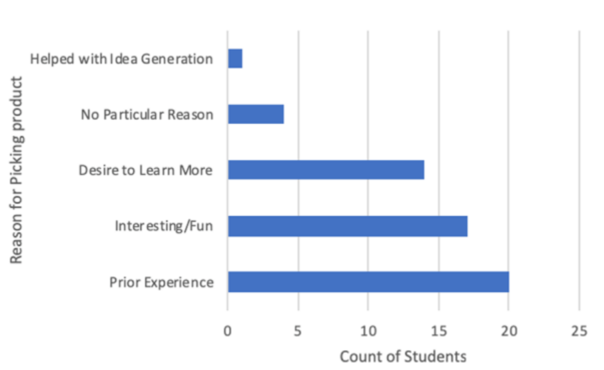

FIGURE 2: CONTENT ANALYSIS RESULTS FOR WHY STUDENTS CHOSE THE PRODUCT THEY DID

While many students did not choose their idea based how useful it would be during idea generation, the next question sought to understand if students were able to use their product to help in idea generation, and if so how. Content analysis revealed that 29 participants found their dissected product to be useful while 27 participants did not find it to be useful. This number was lower than expected since student responses to the closed response question "I was able to draw inspiration from the product I dissected during idea generation" (participant #53) were above average, with 34 students reporting 5 or higher. One student who was able to draw inspiration from their dissected product said "one interesting idea I came up with was based on the spring mechanism of the nerf gun" (participant #16). other students did not directly reuse parts for their idea generation but instead gained value from identifying the bigger picture saying "it made me realize how many parts actually go into a product" (participant #5) or "it gave me the idea to transfer power from a motor to multiple parts of a product." (participant #36). To get a more detailed look at how condition (design task or instructional material) may have been impacting students' abilities to see the usefulness of dissected products during idea generation, we looked at each condition separately, see Figure 3.

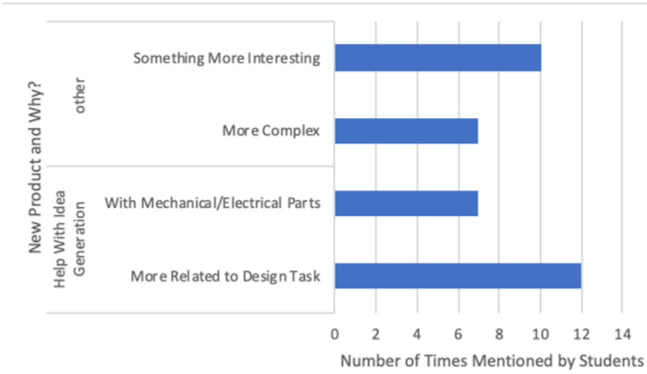

FIGURE 4: CONTENT ANALYSIS RESULTS FOR " WHAT PRODUCT WOULD YOU PICK NEXT TIME AND WHY?"

Overall, more of the students tasked with designing a water toy found their dissected product to be useful for idea generation than students tasked with designing an alarm clock. These results align with prior analysis, which revealed a statistically significant main effect of the design task on value of dissection. In addition, we looked at how the instructional material given to students affected how useful they found their dissected product to be for idea generation. Content analysis revealed that students with worksheet B found their dissected product to be more useful for idea generation than students with worksheet A. This is result is in alignment of our hypothesis that the instructional material would impact how students were able to relate product dissection to their idea generation activity. Specifically, worksheet B asked students to further describe applications for their dissected product. These results indicate that the addition of this question in the instructional material had an effect on students' ability to draw inspiration from their dissected product.

The final question, (Figure 4), asked students' what product they might pick if they could pick something else, see Figure 4. One participant said, "I would probably pick the milk frother, because the vibrating factor of the tool might be useful." (participant #37). A total of 36 out of the 56 students surveyed indicated that they would select a different product to dissect if given the choice. This is insightful because it shows that

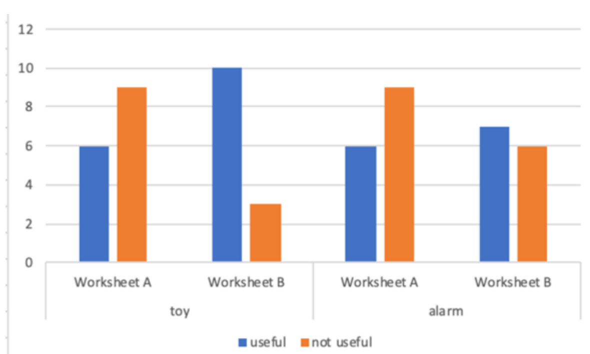

FIGURE 3: PERCEIVED USEFULNESS OF DISSECTED PRODUCT FOR IDEA GENERATION

students may be able to gain more inspiration from products that are analogically closer, similar to the results of the previous two questions.

Discussion and Implications for Engineering Education

The main goal of this paper was to investigate the benefits of product dissection modules in engineering education. Specifically, we aimed to understand if students would intrinsically be motivated to complete dissection and get insights into their perceptions of the module. The main findings from this paper were as follows:

- Students were intrinsically motivated to complete product dissection (valuable, useful, enjoyable)
- Students thought dissection was more valuable when completing the water toy design task
- Students chose products to dissect based on familiarity and interest
- Students had a positive sentiment towards all aspects of the product dissection module
- When students had instructions that emphasized using dissection for inspiration, they thought dissection was more useful for idea generation.

A discussion of our results and their implications for engineering education are examined in the following sub-sections.

Students are Motivated to Dissect, but the Design Task Impacts Motivation

Through this research, we aimed to understand if students were intrinsically motivated to perform dissection. Our first hypothesis was that students would intrinsically motivated to perform product dissection and that the design task and the instructional materials would influence this intrinsic motivation. The first part of our hypothesis was confirmed when students indicated above average scores for usefulness, value, and enjoyment of the dissection module. These results indicate that the product dissection modules will be well received by students in engineering classrooms and that they should be integrated into engineering design courses.

We also saw that there were no differences in usefulness and enjoyment between the design task and the instructional materials (worksheet). However, it was determined, that students did find the dissection module to be more valuable if they completed the water toy design task. These results reveal that the design task does play a role in how motivated students are and that it is related to the value that they find in the module, and therefore their intrinsic motivation to complete product dissection [19]. This is in alignment with the results from content analysis, which revealed that more students who were given the toy design task were able to utilize product dissection during idea generation than students who were given the alarm design task. These findings may be due to the products that students are choosing to dissect or the products that are available for dissection since findings from our content analysis show that students who did not find the dissection to be useful commented on the lack of similarity between their dissected product and the one, they were trying to design.

These results shed light on factors that should be considered as these modules are implemented in engineering design classrooms. Specifically, the design task that is being paired with product dissection should be chosen thoughtfully and appropriate products should be available to support that design task. As we continue this research, our online repository for products will grow to support more activities.

Students had a Positive Reaction to the Product Dissection Module

In addition to understanding intrinsic motivation, this research aimed to understand what parts of the dissection module students found useful/enjoyable. We hypothesized that students would find all aspects of the product dissection module useful, regardless of their condition (design task or instructional materials) since the development of this module was grounded in previous research in product dissection. Students found every component of the module, that was identified in the survey, to be useful/enjoyable, regardless of their specific task or worksheet. Participants felt that the product dissection module was designed appropriately and that they had enough time to complete the activity. This is important because it shows that the participants thought the modules were organized effectively. These results indicate that these activities will be well received by students when implemented in a classroom environment. While students had a positive sentiment towards the dissection module most of the median values were a 5 on our 1-7 scale, indicating that there is still room for improvement in the module. Areas for improvement were identified through content analysis of the open response questions asked to students at the end of the module.

Students are choosing products based on interest, not usefulness

Since previous research found that there were no differences in creativity between different products dissected [25], this module allowed students to choose any product from the product dissection website. While the instructions clearly state that the "goal is to understand strengths and weaknesses of the product in order to develop new innovative concepts that satisfy the design goal" followed by their design task (toy/alarm), most students did not choose their product with this in mind. In fact, only *one* student identified "help with idea generation" as their reason for picking the product they dissected. These results show that there is a major disconnect between the written instructions and student decisions, with students choosing products because they are familiar to them rather than because they feel that they will be useful for idea generation.

Although students picked products based on interest, when asked at the end of the module what product they would dissect if they could pick something else, 12 participants identified that they would choose products to facilitate their idea generation in future iterations of dissection activities. This realization is important because it shows that students are making a connection between the product chosen for dissection and the idea generation, which is one of the main purposes of this module.

Due to these results, we suggest that more emphasis be placed on the purpose of the dissection at the beginning of the module in order to encourage students to choose products to facilitate idea generation. Since students are able to make a connection between the product they choose to dissect and their ability to relate it to the design task after they have completed the module, it may be useful to add a short example problem to show the value of product dissection in idea generation before moving to the main design task.

Emphasis should be placed on using dissection for inspiration in idea generation

Students were given one of two different instructional materials (Worksheet A or B) to complete during their dissection activity. While there were no differences in perceptions of the dissection activity based on the different worksheets, the open response questions uncovered benefits of Worksheet B, which includes an additional question to support using product dissection as a source of inspiration during idea generation. The application aspect of this worksheet had students think one stop further than just dissecting their product and helped them to make the connection between the product and the design task. While this worksheet requires students to complete some extra work during their 15-minute dissection time, students did not find this extra requirement burdensome as evidenced by the lack of difference between responses between instructional material conditions for the question "I had enough time (15 min) to complete my dissection activity".

The results from the content analysis, paired with results from the survey responses indicates that Worksheet B is a more appropriate instructional material to use in engineering design classrooms when focusing on how product dissection can be used as a source of inspiration for idea generation. Along with the use of Worksheet B, educators should emphasize the design task throughout the module to ensure that students are thoughtfully choosing their products and using the materials to the fullest extent.

CONCLUSION AND FUTURE WORK

The purpose of this study was to examine students' perceptions on the usefulness and value of product dissection modules for learning about how a product works and generating ideas for a given design task. A limitation with this study was that the sample size of 56 students. Future work should explore this study in more classrooms so as to generate a larger variety of data. In addition, this study used a guest lecturer to implement product dissection modules. To make this study more representative of how the product dissection module would be implemented in the classroom, professors should be trained on the implementation of dissection modules for use in their own classrooms. While this study gave us insights into student perceptions of the dissection modules, additional work is needed in order to gain insights into instructors' perceptions of the activity. Future deployment to multiple universities and professors will give greater insight into the effectiveness of product dissection modules in different engineering design classrooms.

Despite limitations, this study presented many key findings that are insightful for engineering education. Our key findings were as follows: (1) Students were intrinsically motivated to complete product dissection (valuable, useful, enjoyable), (2) students thought dissection was more valuable when completing the water toy design task, (3) students chose products to dissect based on familiarity and interest, (4) students had a positive sentiment towards all aspects of the product dissection module, (5) when students had instructions that emphasized using dissection for inspiration they thought dissection was more useful for idea generation.

This is the first study to systematically assess the developed product dissection modules for student perceptions of the activity and their intrinsic motivation to complete the activity. It is encouraging that the majority of students had high values for perceived usefulness and value of the product dissection activity and future work aims to investigate how to increase this perceived usefulness/value. This study offers good insight into how product dissection activities can be useful in engineering education and how the modules can be modified for future implementation.

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REFERENCES

[1] Bloom, B. S., 1956, "Taxonomy of Educational Objectives: The Classification of Education Goals," B. S. Bloom, ed., Susan Fauer Company, Inc.

[2] Anderson, L. W., Krathwohl, D. R., Airasian, K. A., Cruikshank, R. W., Mayer, O. R., Pintrich, P. R., Raths, J., and Wittrock, M. C., 2001, A taxonomy for learning, teaching and assessing: a revision of Bloom's Taxonomy of Educational Objectives, Longman, New York.

[3] Bransford, J. D., Brown, A. L., and Cocking, R. R., 1999, How people learn: Brain, mind, experience, and school, National Academy Press.

[4] Dutson, A. J., Todd, R. H., Magleby, S. P., and Sorensen, C. D. J. J. o. E. E., 1997, "A review of literature on teaching engineering design through project-oriented capstone courses," 86(1), pp. 17-28.

[5] Abdulwahed, M., and Nagy, Z. K., 2009, "Applying Kolb's experiential learning cycle for laboratory education," Journal of engineering education, 98(3), pp. 283-294.

[6] Froyd, J. E., Wankat, P. C., and Smith, K. A., 2012, "Five major shifts in 100 years of engineering education," Proceedings of the IEEE, 100(Special Centennial Issue), pp. 1344-1360.

[7] Jamieson, L. H., and Lohmann, J. R., 2012, "Innovation with impact: Creating a culture for scholarly and systematic innovation in engineering education," ASEE.

[8] Lewis, K., Moore-Russo, D., Cormier, P., Olewnik, A., Kremer, G., Tucker, C., Simpson, T., and Ashour, O., "The assessment of product archaeology as a platform for contextualizing engineering design," Proc. ASME 2013 International Design Engineering Technical Conferences and Computers and Information in Engineering Conference, American Society of Mechanical Engineers, pp. V001T004A024-V001T004A024.

[9] Hynes, M., Portsmore, M., Dare, E., Milto, E., Rogers, C., Hammer, D., and Carberry, A., 2011, "Infusing engineering design into high school STEM courses."

[10] Starkey, E., McKay, A., Hunter, S., and Miller, S., 2017, "Dissecting Creativity: How Dissection Virtuality, Analogical Distance, and Product Complexity Impact Creativity and Self-Efficacy," Design Computing and Cognition'16, Springer, pp. 59-77.

[11] Toh, C. A., and Miller, S. R., "Visual Inspection or Product Dissection? The Impact of Designer-Product Interactions on Engineering Design Creativity," Proc. ASME 2013 International Design Engineering Technical Conferences and Computers and Information in Engineering Conference, American Society of Mechanical Engineers, pp. V005T006A011-V005T006A011.

[12] Toh, C. A., and Miller, S. R., "Exploring the utility of product dissection for early-phase idea generation," Proc. ASME 2013 International Design Engineering Technical Conferences and Computers and Information in Engineering Conference, American Society of Mechanical Engineers, pp. V005T006A034-V005T006A034.

[13] Toh, C. A., Miller, S. R., and Kremer, G. E. O., "The impact of product dissection activities on the novelty of design outcomes," Proc. ASME 2012 International Design Engineering Technical Conferences and Computers and Information in Engineering Conference, American Society of Mechanical Engineers, pp. 615-624.

[14] Alzayed, M. A., McComb, C., Hunter, S. T., and Miller, S. R., 2019, "Expanding the Solution Space in Engineering Design Education: A Simulation-Based Investigation of Product Dissection," Journal of Mechanical Design, 141(3), p. 032001.

[15] Starkey, E. M., McKay, A. S., Hunter, S. T., and Miller, S. R., "Let’s get physical? The impact of dissection modality on engineering student design learning," Proc. ASME 2016 International Design Engineering Technical Conferences and Computers and Information in Engineering Conference, American Society of Mechanical Engineers, pp. V003T004A015-V003T004A015.

[16] Starkey, E. M., McKay, A. S., Hunter, S. T., and Miller, S. R. J. J. o. M. D., 2018, "Piecing Together Product Dissection: How Dissection Conditions Impact Student Conceptual Understanding and Cognitive Load," 140(5), p. 052001.

[17] McKenna, A. F., Chen, W., and Simpson, T. W., "Exploring the impact of virtual and physical dissection activities on students’ understanding of engineering design principles," Proc. ASME 2008 International Design Engineering Technical Conferences and Computers and Information in Engineering Conference,

American Society of Mechanical Engineers, pp. 359-368.
[18] Grantham, K., Okudan, G., Simpson, T. W., and Ashour, O., "A study on situated cognition: product dissection's effect on redesign activities," Proc. ASME 2010 International Design Engineering Technical Conferences and Computers and Information in Engineering Conference, American Society of Mechanical Engineers, pp. 617-626.
[19] Ryan, R. M., and Deci, E. L. J. C. e. p., 2000, "Intrinsic and extrinsic motivations: Classic definitions and new directions," 25(1), pp. 54-67.
[20] Bhatnagar, A., 2015, "Product Dissection: A Method for Hands on Engineering Education," Journal of Engineering Education Transformations, pp. 99-104.
[21] Christine Toh, S. M., & Tim Simpson, 2015, "The impact of virtual product dissection environments on student design learning and self-efficacy," Journal of Engineering Design, pp. 48-73.
[22] Toh, C. A., and Miller, S. R. J. D. S., 2015, "How engineering teams select design concepts: A view through the lens of creativity," 38, pp. 111-138.
[23] Goldenberg, J., Lehmann, D. R., and Mazursky, D. J. M. s., 2001, "The idea itself and the circumstances of its emergence as predictors of new product success," 47(1), pp. 69-84.
[24] Moore-Russo, D., Grantham, K., Lewis, K., and Bateman, S. M., 2010, "Comparing physical and cyber-enhanced product dissection: Analysis from multiple perspectives," International Journal of Engineering Education, 26(6), p. 1378.
[25] Starkey, E. M., Hunter, S. T., and Miller, S. R. J. J. o. M. D., 2019, "Are Creativity and Self-Efficacy at Odds? An Exploration in Variations of Product Dissection in Engineering Education," 141(1), p. 012001.
[26] Starkey, E. M., McKay, A. S., Hunter, S. T., and Miller, S. R., 2018, "Piecing Together Product Dissection: How Dissection Conditions Impact Student Conceptual Understanding and Cognitive Load," Journal of Mechanical Design, 140(5), p. 052001.
[27] Carlson, L. E., and Sullivan, J. F., 1999, "Hands-on engineering: learning by doing in the integrated teaching and learning program," International Journal of Engineering Education, 15(1), pp. 20-31.
[28] Bonwell, C. C., and Eison, J. A., 1991, Active Learning: Creating Excitement in the Classroom. 1991 ASHE-ERIC Higher Education Reports, ERIC.
[29] Abeysekera, L., Dawson, P. J. H. E. R., and Development, 2015, "Motivation and cognitive load in the flipped classroom: definition, rationale and a call for research," 34(1), pp. 1-14.
[30] Zappe, S., Leicht, R., Messner, J., Litzinger, T., and Lee, H. W., "" Flipping" the classroom to explore active learning in a large undergraduate course," Proc. ASEE Annual Conference and Exposition, Conference Proceedings.
[31] Matusovich, H. M., Paretti, M. C., McNair, L. D., and Hixson, C., 2014, "Faculty motivation: A gateway to transforming engineering education," Journal of Engineering Education, 103(2), pp. 302-330.
[32] Sansone, C., and Harackiewicz, J. M., 2000, Intrinsic and extrinsic motivation: The search for optimal motivation and performance, Elsevier.
[33] White, R. W. J. P. r., 1959, "Motivation reconsidered: The concept of competence," 66(5), p. 297.
[34] Dev, P. C. J. R., and education, s., 1997, "Intrinsic motivation and academic achievement: What does their relationship imply for the classroom teacher?," 18(1), pp. 12-19.
[35] Deci, E. L., Koestner, R., and Ryan, R. M. J. R. o. e. r., 2001, "Extrinsic rewards and intrinsic motivation in education: Reconsidered once again," 71(1), pp. 1-27.
[36] Skinner, B. F., 1953, Science and human behavior, Simon and Schuster.
[37] McAuley, E., Duncan, T., Tammen, V. V. J. R. q. f. e., and sport, 1989, "Psychometric properties of the Intrinsic Motivation Inventory in a competitive sport setting: A confirmatory factor analysis," 60(1), pp. 48-58.
[38] Tierney, P., and Farmer, S. M., 2002, "Creative self-efficacy: Its potential antecedents and relationship to creative performance," Academy of Management Journal, 45(6), pp. 1137-1148.
[39] Guildford, J., Christensen, P., Merrifield, P., and Wilson, R., 1978, "Alternate uses: Manual of instructions and interpretation," Orange, CA: Sheridan Psychological Services.
[40] Bertram, D., 2007, "Likert scales," Retrieved November, 2, p. 2013.
[41] Mathisen, G. E., and Bronnick, K. S. J. I. J. o. E. R., 2009, "Creative self-efficacy: An intervention study," 48(1), pp. 21-29.
[42] Carley, K., 1990, "Content analysis. The Encyclopedia of Language and. Linguistics. RE Asher, Ed," Pergamon Press, Edinburgh.