DESIGN WITHOUT MAKE: A FEASIBLE DIRECTION FOR AMERICAN TECHNOLOGY EDUCATION

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ABSTRACT

This paper describes the second part of a new three-part study of STEM and engineering design research – termed Design–Without–Make conducted by NC State University in 2009–10 in an NC high school. The hybrid quantitative, qualitative case study is being developed with the purpose of capturing what new technological learning occurs and how the new pedagogical learning benefits the technological learner. The first paper described a basic literature review, social learning theory, project-based learning study and the outline and aims of the study. This second paper in the sequence goes on to explain the main study and the major data results and findings for this new approach to teaching engineering design technology within STEM education.

The main purpose of this study was: i) To assess whether students who participate in design-without-make activities achieve learning outcomes as successfully as or better than students of traditional design-with-make activities; ii) To determine student and teacher attitudes towards design-without-make activities within technology education. A one-way analysis of variance was conducted to evaluate the relationship between instruction and the change in pre- and post-test scores between groups.

The study consisted of 27 non-random participants, with the control group having 10 participants and the treatment group having 17 participants. The mean score from both groups came to 14.37 (SD=5.43), with a standard error of 1.05. The post-test scores ranged from 4 to 22 out of a possible score of 22. With F=2.04, p=.05, it was found there were no significant differences between the control and treatment post-test scores.

Keywords: Project-Based Learning, Design-With-Make, Design-Without-Make, STEM Education.

FRAMEWORK OF PAPER

In a previous paper, the authors described the literature, and the learning framework relevance and scholarship to engineering design, (Thompson, Varnado, & Matthews (2009). A feasible direction for American Technology Education, i-manager's Journal of Educational Technology, VOL #5 Issue No. 4 April-June, 2009).

In this paper the authors will review the main design-without-make study, and its pedagogical approach to teaching engineering design within STEM technology. It is their belief, that this student-centered, intuitive practice has a lot of potential to play an important role in moving forward STEM education. Barlex (2008) was also of this mindset, and in the International Journal of Technology and Design Education (2007), he heuristically suggests that while still a hands-on project-based approach, design-without-make saves time and money, and allows for greater student design creativity. And that it places more emphasis on teaching and learning the design process rather than focusing on mechanistic prototyping outcomes.

INTRODUCTION

Current technology education in North Carolina is built around the concept of 'hands-on' laboratory exercises that allow students to gain real-world experiences in developing, implementing, and evaluating technologies (NCDPI, 2006). These N.C. Technology Programs of Study consist of 14 core strands, eight pre-engineering strands and three visualization strands; the courses of study are located at: http://www.ncpublicschools.org/cte/technology/curriculum/programs/. Specifically, these strands are used as specific courses of study in order to allow a student to explore basic and advanced technological concepts and principles that can be related to a chosen career.

Nevertheless, in the Pre-engineering Strand is the Introduction to Engineering Design core. And within this strand are the students objectives which are used to create a product based on the principles and elements of design. This Engineering Design strand is where Design-Without-Make was tested, as it fulfilled the requirements for this standard course of study.

The state objectives which are listed below, were followed closely

- Identify the principles and elements of design
- Describe how the design process relates to technology and other disciplines
- Create a product based on the principles and elements of design

Prior Knowledge

The high school students entering this design topic lesson were expected to have pre-requisite basic knowledge of (i) Technology, (ii) its past, and (iii) what constituted a technological system before starting the lesson. Without this knowledge it would have been difficult for students to see how individual components in the system related to the part they were designing. Plus, prior to beginning this lesson students were expected to have read pages 145-147 and Chapter 9 in Technology: Today and Tomorrow by Brusic, et al (1999). They were also expected to reference their designs back to Chapters 7 & 9 from the class text.

Teacher input and the process

Teachers were provided with given lesson plans which included a design PowerPoint (Thompson, 2009). Within the lesson plans a teacher had to outline the basics of the design process to include: design definition, design brief, design principles, design process and design proposal. The teacher had to discuss the 6 elements of design: line, shape, form, texture/shade, and color. Teachers also had to discuss and explain the 7 principles of design: balance, proportion, contrast, variety, harmony, unity, rhythm. Included were the 8 factors of design: safety, reliability, economic consideration, quality control, environmental concerns, manufacturability, maintenance/repair, and ergonomics. In class it was expected that the discussion was centered on how the elements, principles, and factors of design work together throughout the design process and how each connected into Barlex's design pentagon, as seen in Figure 1.

Design-Without-Make Activity

At this juncture of teacher input, students were separated into random groups. Within the groups they were asked to research a new technology and to design a new implementation of that technology to solve a real world problem. Students had to follow the design process outlined in the PowerPoint (Thompson, 2009), which started with problem identification, and continued through brainstorming, rough sketching, and comprehensive layouts, and finished with presentation graphics. Sometimes teacher input was required to assist students in choosing a technology and problem. Finally, students then presented their designs to their peers for critique and evaluation. As shown in Table 1, a rubric was created to allow teachers to grade design results.

Basic Methodology and Experiment Design

The basic methodology for this blended study consists of both quantitative and qualitative components. In the quantitative component a non-equivalent quasi-experimental design is used. In the control group it used a traditional design-with-make class, while the treatment group consisted of a design-without-make class. Both groups were presented with equivalent pre- and post-tests, which were compared statistically using an ANOVA test. The qualitative data was collected in semi-structured teacher and student interviews. The whole experiment was based

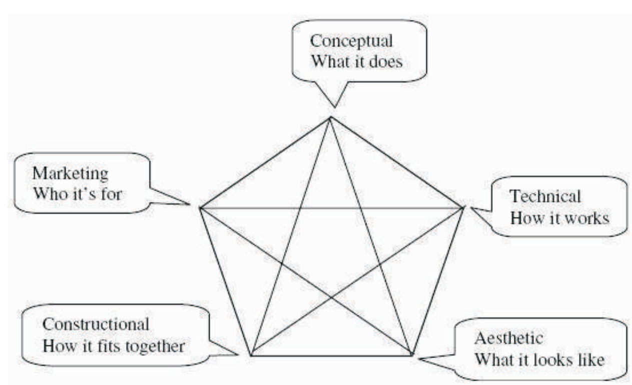

Figure 1. The design decision pentagon

Objectives	4 points	4 points	12 points	20 points per objective
Brainstorming and research of information	Individual or group sharing of ideas	Organization skills and recording of ideas	Evaluation of ideas upon completion of gathering thoughts through more in depth research material with attention to references	
Thumbnails, working drawings, or desktop publishing	Pencil/ ink layout/ Mechanical/ CAD/ Desktop Publishing format	Organization skills and recording of ideas Layout and positioning of drawings	Finals layout of thumbnails, working drawings including line structure, dimensions, details and notes	
Marketing Display	Materials or software used related to display development	Attention to details	Final production of display including shape, form, function, harmony, and balance	
Technical reporting or portfolio development	Data collection and processing of information	Details of the design methods and procedures	Composite of all necessary elements along with details within the portfolio	
Marketing Presentation	Design presentation selections and supply list	Presentation methods	Final presentation of display in relations to following the Principles and Elements of Design	
	Total Points:			
	Comments:			

Table 1. Rubric to student group designs

on social learning theory – and its relevance to engineering design. This is connected to Problem Based Learning practice of design-without-make which in turn is intrinsically linked to social learning theory, and design and creativity within the engineering design classroom as shown in the Table 2.

SocialNetworking and Learning – Relevant to STEM Engineering Design	Pertinent authors & scholarship
Social learning theory In this digital age there are many forms of social learning especially when students are not limited to the classroom walls. Students often bond to each other through social interaction; learn from each other by close proximity; or learn by watching others working together. Modern digital savvy students also connect via social interaction outside the classroom. Students use email, twitter, facebook, blogs, virtual objects, and so on to communicate with each other. Social learning theory focuses on the learning that occurs within a social context. Thus, students learn and reason verbally and the teacher / mentor / parent acts as a collaborator to provide positive and appropriate social interaction in order to learn from each another. The theory considers that through social interaction students learn from one another. It includes such concepts as observational learning, imitation, self-efficacy, self-regulation, motivation and modeling (live and/or symbolic modeling). Bandura directed his initial research to the role of social modeling in human motivation, thought, and action. Albert Bandura is considered one of the leading proponents of this theory, but Bandura never looked at digital connections as communication.	Bandura (1977); Vygotsky (1978); Davydov & Kerr (1995); John-Steiner (2000); Murphy & Hennessy (2001); Trebell (2007); Gredler (2005) Marton & Saljo (1976
Design and Creativity Sternburg cites it as a method of educating students to effectively use knowledge and skills in what is called educating for wisdom. (Wisdom being made up of a combination of intelligence, creativity, and wisdom, which in turn is influenced by one's personal value system on interpersonal, intrapersonal, and extrapersonal levels. Spendlove uses the Intrinsic Motivation Theory Principle of Creativity. He defines that intrinsic, emotionally engaging activities are highly conducive to creative acts. He also lists five 'sure-fire' killers of creativity, which are: expected reward, expected evaluation, surveillance, time limits and completion.	Sternberg, Reznitskay & Jarvin (2007); Standards for Technological Literacy; ITEA; Badran (2007) ; Spendlove (2007)
Problem - and Project-based learning A method of teaching problem-solving skills in which students work together as they progress through a series of steps to design, implement, and evaluate solutions to real world problems. In both Problem- and Project-based learning (PBL), the teacher provides complex tasks based on challenging questions or problems that involve the students' problem solving, decision making, investigative skills, and reflection that include teacher facilitation, but not direction. The teacher is more a facilitator and more focused on questions that drive students to encounter the central concepts and principles of a subject hands-on.	Mills (2003); Banks and Jackson (2007); Matthews (2004); Albanese & Mitchell (2003); Lambros (2002)
Design-with-make Design-with-make uses six basic steps in every Technology Education design-with-make activity. They are 1. Identify and clarify problems; 2. Conduct research which might involve investigations; 3. Generate one or more design proposals; develop these so that they can be scrutinized for predicted performance and social/environmental impact; 4. Construct a prototype of the most promising design; 5. Experiment with sub-component designs as necessary; 6. Test/evaluate the constructed solution.	Spendlove (2007); Kipperman & Sanders (2007); Trebell (2007); Badran (2007); Schwartz (2007)
Design without-make The methodology allows students to come into contact with creative design experiences without emphasis on building or project construction. A design-without-make activity is designed around six key concepts. These are 1. The Students design, but do not make; 2. They design products and services for the future; 3. They use new and emerging technologies in their design proposals; 4. They write their own design briefs; 5. They work in teams/ groups"; 6. They present their proposals to their peers, teachers, and mentors and to adult audiences at innovative conferences. Teachers are encouraged to challenge students with design-without-make activities which forces students to design products based on conceptual (what it does), technical (how it works), aesthetic (what it looks like), constructional (how it fits together), and marketing (who it's for) criteria without actually having to manufacture a final product for grading.	Barlex (2007); Barlex & Trebell (2008); Banks & Jackson (2007); Atkinson (2000); Peterson (2001)

Table 2. Social Learning Theory – Relevance to Engineering Design Literature

Social Learning Theories – Review of Literature

Success in education can be directly linked to research done in social learning by Vygotsky (1978), Davydov (1995), John-Steiner (2000), Murphy & Hennessy (2001). Trebell

(2007) states that designing is a "social activity drawing on interaction between pupil/pupil and pupil/teacher" (p. 2). Teaching tools such as scaffolding and group work are very important in the social learning classroom. Vygotsky (1978), states "[t]he tasks that the child can accomplish in collaboration with the teacher today, she can accomplish alone tomorrow" (as cited in Gredler, 2005, p. 324). He encourages teachers to challenge students by designing lessons that kept students in their Zone of Proximal Development, which is a level of performance just above what the student can achieve on their own, but not more than they can achieve with the teacher's help. He concluded that students learn and reason verbally and that the teacher was only there to provide the social interaction which the students needed since students learn through social interactions with knowledgeable members of culture (Gredler, 2005).

Design-With-Make

Traditionally technology educators have used design-with-make projects to enhance, encourage, and allow for creativity among its students. After all, when students are provided with LEGO™ robotics programming modules, they can easily create and develop interactive storylines and props to accompany any discipline; even literature (Berg et. al, 2008). However, research has shown that, "[p]oor practice with education is often focused for reasons of expediency on the product stages of the creative process and in doing so bypassing the essential creative (person) and learning (process) elements and resulting in embellished, rather than creative, novel and inspiring, outcomes with limited contextualized learning, emotional engagement or opportunities to engage in risk taking and uncertainty" (Spendlove, 2007, p. 53).

Kipperman and Sanders (2007) outline six basic steps in every Technology Education design-with-make activity. They are "i). Identify and clarify problems; ii). Conduct research which might involve investigations; iii). Generate one or more design proposals; iv). Develop these so that they can be scrutinized for predicted performance and social/environmental impact; v). Construct a prototype of the most promising design, experimenting with subcomponent designs as necessary; and vi). Test/evaluate the constructed solution" (p.227). They also recommend that "during this process the students should document all design, construction and testing procedures" (Kipperman, 2007, p. 227).

Design-Without-Make

A design-without-make activity is designed around six key concepts. These are "pupils design, but not make"; "pupils design products and services for the future"; "pupils use new and emerging technologies in their design proposals"; "pupils write their own design briefs"; "pupils work in groups"; and "pupils present their proposals to their peers, teachers and mentors and to adult audiences at innovation conferences" (Barlex & Trebell, 2008, p. 124). In their article, Design-without-make: Challenging the conventional approach to teaching and learning in a design and technology classroom, Barlex and Trebell (2008), define creative activities as "having four characteristics: (i), imaginative thought or behavior, (ii) purpose, (iii) originality (new to the creator) and (iv) an outcome of value" (p.121). They also acknowledge that to develop creativity, "children must be actively involved in the learning process…[and] group work and collaboration are now seen as key elements" (Barlex & Trebell, 2008, p.121). Barlex and Trebell encourage teachers to challenge students with design-without-make activities which force students to design products based on conceptual (what it does), technical (how it works), aesthetic (what it looks like), constructional (how it fits together), and marketing (who it's for) criteria without actually having to manufacture a final product for grading (Barlex, 2007, Barlex & Trebell, 2008).

Design-without-make activities work well in creative learning environments as defined by Isaksen (1994). He concludes that the more challenge, freedom, support, trust, prestige-free discussions, humor, and risk-taking the individual perceived in the immediate social work environment the more opportunity students have to be creative. This description is closely linked to the beliefs Barlex (2007) identifies as necessary for teachers who wish to host design-without-make activities in their classroom. He says teachers who believe "students intellectual abilities are socially and culturally developed"; "tasks need to be culturally authentic"; "prior knowledge and cultural perspectives shape new learning"; "learners construct rather than receive meaning"; "pupils share responsibility for learning with teachers"; and "pupils are motivated by dilemmas to which they are emotionally committed" (Barlex, 2007, p.156), will be most successful at integrating design-without-make activities.

Banks and Jackson (2007) point out how, despite many students being motivated to take technology courses because of the hands-on process of physically making a product, these physical artifacts often lack any creativity or innovation on the point of the student, due to teacher designed plans. While these projects are easy to implement and fun for students to complete, often they are evaluated based on the completion of the product and an accompanying portfolio activity. In his research, Atkinson (2000) describes how when it comes to portfolio evaluation teachers tend to reward 'thin' evidence before rewarding students for exhibiting higher-order thinking skills. Barlex (2007) in a series of interviews with students in design and make classrooms learned that students tend to develop design portfolios after the product has been completed, which undermines the entire portfolio activity. When an entire class of students' products are identical in appearance and they are not performing the proper design and problem solving processes during the creation phases of said products, are they putting innovation in action? More simply stated, are these students studying technology effectively?

This is the case for implementing design-without-make activities into Technology Education classrooms. Barlex's research has "revealed that pupils can be successfully engaged in designing without attendant making and that the current use of the portfolio for assessment purposes is for many pupils a highly demotivating experience" (2007, p.160). He attributes this 'demotivation' to the fact of students not recognizing the value of the portfolio due to the way in which it is ineffectively implemented with the project, while he also points out that "the advantages of collaboration between pupils can be lost when there is an over emphasis on making" (Barlex, 2007, p.160).

Advantages of Design-Without-Make

The implementation of design-without-make activities in place of some design-with-make activities within the Technology Education classroom has many advantages. First, design-with-make is often approached as if the act of designing is a linear process, rather than an inter-connected, reflective, non-linear series of steps (Barlex, 2008). Figure 1 shows Barlex's design decision pentagon, which demonstrated the interconnectedness of the elements within the non-linear approach to designing taught in design-without-make activities. Second, group work and active involvement in the learning process, and risk-taking are all encouraged in design-without-make activities (Barlex, 2008, Trebell, 2007). These happen to also be important aspects of a creative learning environment, which is necessary for students to be innovative designers. A third major advantage of design-without-make in the classroom is the lack of large amounts of physical resources required in traditional design-with-make activities, such as: tools, equipment, and consumable materials (Barlex, 2007).

Research Questions

The research questions this study sought to address include:

- Did students who participated in design-without-make activities achieve learning outcomes as successfully as students of traditional design-with-make activities?
- What are student and teacher attitudes towards design-without-make activities within technology education?

Research Hypotheses

The following research hypotheses identify the study testing instruments and subsequent data analysis:

HO_1: There will be no significant difference in knowledge gain between the traditional design-with-make (control) and design-without-make (treatment) groups.

HO_2: There will be no significant difference in attitudes between the traditional design-with-make (control) and design-without-make (treatment) groups.

HO_3: There will be no significant difference in the effectiveness of the traditional design-with-make (control) and design-without-make (treatment) groups.

Population Sample

Due to the non-random sampling present in the convenience sample taken, accurate generalization across the population was not possible. The sample chosen for this study consisted of two high school 'Fundamentals of Technology' courses being taught by the same instructor. The classes consisted of a total of 27 students, which is enough for statistical analysis to take place (Agresti & Finlay, 1997).

Control Group

For this study, after the pre-test, the control group received a standard course of instruction in design principles and elements, consisting of a design-with-make reinforcement activity. Instruction consisted of a PowerPoint lecture on the principles and elements of design, while the design-with-make activity was reserved for students to design and construct a 2D or 3D advertisement for the technology of their choice. The lesson plans and PowerPoint, as well as activity guidelines, can be found in the Appendix of Thompson, (2009). After completion of this course of instruction, students received the post-test and performance was evaluated.

Experimental Group

The experimental group also started with the pre-test, which was identical to the pre-test taken by the control group. Students then received the treatment, which consists of a PowerPoint lecture on the principles and elements of design which was geared towards the completion of a design-without-make activity. For the design-without-make experiment activity students were asked to brainstorm and research an emerging technology. They were then asked to design a new product for presentation to the class, in which the new technology they had researched could be used to solve a real-world problem they have identified. Lesson plans, PowerPoint, and activity guidelines, can be found in the Appendix of Thompson, (2009) an unpublished Masters Thesis. After students have completed their presentations to the class, they took the post-test and their performance was evaluated. Again, the post-test for the experimental group is identical to the post-test of the control group.

Procedure

Two high school Fundamentals of Technology classes were randomly chosen and parental permission obtained for subject participation. This study was planned around a set of strict guidelines and took place during the week of March 16, 2009. One week prior, the researcher and the cooperating teacher met for a 2 hour teacher training session on the treatment pedagogy. The researcher outlined the entire study, the new instructional method, and provided the teacher with a set of materials relating to the instructional unit and activities. The researcher also introduced the subjects to the study.

Upon the start of this study, both groups took a pre-test. Next they were taught virtually identical lessons on the unit material, with the only difference being slides related to the activities students would be doing in conjunction with the lessons. After completing the lectures, students were given handouts corresponding to the activities designed for their particular group within the study. Subjects then used the remainder of the week of instruction to complete the assigned projects and present them to their peer group. Once the unit requirements and study time had been fulfilled, students took the post-test. Throughout the study duration, the researcher gathered observational data relating to student involvement and problems encountered during implementation of the treatment lesson and activity.

At the end of this study, semi-structured interviews were conducted to gain an understanding of teacher and student attitudes towards design-without-make activities within the classroom. One teacher and two students involved in the design-without-make activity were interviewed. Specific questions asked of the teacher were:

- What are your views on the quality of ideas produced?
- Would you recommend design-without-make to other [technology] teachers?
- Were the ideas produced creative?
- Did pupils come to value the ideas as a product in themselves?
- Did this strategy alienate pupils from the curriculum?

(Barlex & Trebell, 2008, p. 124)

The two student interviewees were asked:

- Their thoughts of design-without-make.
- What they actually designed?

- What they thought of their design?
- Would they have had to design something simpler if that had to make it?
- Would they recommend design-without-make as a means of enhancing design skills?
- Did the unit lead to the production of creative ideas?

(Barlex & Trebell, 2008, p. 124)

Upon completion of the interviews, transcriptions were made and the data was collected into tables showing the question asked as well as the response given. The data was then analyzed and conclusions drawn as to whether a positive or negative attitude was shown towards design-without-make overall.

Testing Instrumentation

The pre-test and post-test were both derived from the non-secure test item bank that all North Carolina Fundamentals of Technology teachers are given with their curriculum guide for the course. Upon the completion of the item bank questions, the test items were evaluated by a panel of professors, teachers, industry professionals, and Department of Public Instruction officials to determine validity of each item (Shown, 2008). Furthermore, reliability tests were performed on the questions as they were pilot tested during development (Shown, 2008). However, to establish reliability of the assessments used within this study, a split-halves correlation was performed comparing individual student performance on similar questions between the pre- and post-tests.

In developing these instruments from the overall item bank, the researcher isolated questions relating to the specific objectives involved in the research study unit. Then duplicate items were eliminated. Next, every other item was chosen for the pre-test and the remaining items were used in the post-test. Both tests were checked to approximate the consistency of items related to topics within the lesson and then one question was deleted from the pretest to make both tests of equal length for ease of comparison.

Data Analysis

After students took the pre-test and post-test, the assessments were scored. And an analysis of covariance was performed to help account for extraneous variables within the study. Upon completion of the covariance, an ANOVA statistical analysis was run to compare effectiveness of objective achievement for each group. These statistics were compared to determine whether a significant difference exists between groups and to see which hypotheses, if any, was correct. An ANOVA was chosen based upon the assumptions that the post-test score is normally distributed for each population as defined by the pre-test, the variances are the same for all populations, and that the sample is randomly chosen from the population (Green & Salkind, 2003, p.161).

The qualitative data was analyzed using keyword coding, which seeks to identify keywords indicating attitudes within the interview transcriptions. The keywords were also assessed based on context to determine whether they exude a generally positive or negative attitude towards the design-without-make process. Additionally, a frequency analysis was run for each question to determine the number of positive and negative comments given by the interviewees. These results were then grouped into charts and conclusions drawn as to student and teacher attitudes towards the design-without-make activity over all.

Analysis

Quantitative Analysis

This analysis section is in two parts: i) Quantitative analysis using descriptive statistics of the gathered data, and ii) Qualitative analysis via brief interviews to teachers and students.

A one-way analysis of variance was conducted to evaluate the relationship between instruction and the change in pre- and post-test scores between groups. The pre-test scores were set as between-subjects factors, because of the comparison of scores between subjects, with two levels (i.e. control and treatment). The post-test score was set as the dependent variable, because of that score's dependence upon the initial pre-test score and instructional methods used. Using SPSS statistical analysis software, the data was analyzed using a univariate linear model and then again using a comparison of means. Both tests yielded identical results.

The study consisted of 27 participants, with the control group having 10 and the treatment group having 17 (Table 3). The mean score from both groups came to 14.37 (SD=5.43), and a standard error of 1.05. As seen in Table 4, post-test scores ranged from 4 to 22 out of a possible score of 22. With F=2.04, p=.05, there were no significant differences between the control and treatment post-test scores.

Variables	Definition		
Groups	Control Treatment		
Independent Variable	Pretest Score		
Dependent Variable	Posttest Score		
Means	Pretest	Posttest	Difference
Treatment	10.88	14.71	3.82
Control	10.7	13.8	3.1

Descriptive Statistics-95% Confidence Intervals of Pairwise Differences in Pretest and Posttest Scores between tests.

Group		M	SD	N
Treatment	Pretest	10.88	3.24	17
	Posttest	14.71	5.02	17
Control	Pretest	10.70	3.92	10
	Posttest	13.80	6.30	10

Table 3. Descriptive Statistics

Control Group

ID#	Pre	Post	Pre-Post Differnece
1	13	14	1
2	6	16	10
3	7	4	-3
4	8	10	2
5	11	17	6
6	9	4	-5
7	11	12	1
8	20	22	2
9	11	19	8
10	11	20	9
		Mean Difference : 3.1	

Treatment Group

ID#	Pre	Post	Pre-Post Differnece
1	6	13	7
2	12	18	6
3	14	22	8
4	9	20	11
5	6	8	2
6	14	21	7
7	13	17	4
8	5	16	11
9	17	13	-4
10	13	8	-55
11	8	5	-3
12	12	14	2
13	12	13	1
14	12	22	10
15	10	13	3
16	10	11	1
17	12	16	4
		Mean Difference : 3.823529	

Table 4. Raw Test Scores

Qualitative Analysis

At the conclusion of the study, brief interviews were conducted involving the teacher and two students, one male and one female. After the interviews, transcriptions were made and the data was analyzed using thematic coding based on the identification of keywords and phrases. The questions asked of the teacher, as well as the teacher's responses can be seen in Thompson (2009), with the student questions and answers being found in the Appendix, (Thompson, 2009),

From this information, keywords/phrases were identified and coded as having a generally positive theme towards design-without-make, or a generally negative theme towards design-without-make. Some of the positive identifiers from the teacher interview were: much higher, not limited, choices, variety, use it all the time, advantage, like, conceptual, far greater, far better, input, and enjoyed. Some of the negative identifiers were: especially the one that were with the make, don't like, not as much, why didn't we get to build something?, disadvantage, non-made, actually fabricate, skills, like making, and enjoy making. Some of the positive identifiers from the student interviews were: interesting, I liked it, awesome, fun, worked out, different, good, nice, it could be useful, yes, and improve. Some of the negative identifiers were: bad group, difference, and didn't work out.

After coding all of the data, frequencies were tabulated and attitudes were inferred from the frequency of positive to negative identifiers. It can be inferred from the data (Table 5) that the teacher had a generally positive view towards design-without-make, with a 2 positive comment to 1 negative comment ratio. It can also be inferred that the teacher can see both advantages and disadvantages to this methodology, but overall, they had a positive outlook for design-without-make. It can be inferred from the data (Table 6) that the students combined had a generally positive view towards design-without-make, with over 3 positive comments to every 1 negative comment. It can also be inferred that Student 1 had a much more positive

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Totals
Positive	4	2	2	3	3	3	0	3	20
Negative	0	0	1	1	3	0	3	2	10

Table 5.Overall Responses: Teacher

Overall Responses: Students (combined)								
	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Totals
Positive	9	0	3	1	2	3	0	18
Negative	3	0	1	1	0	0	0	5
Overall Responses: Student 1								
	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Totals
Positive	4	0	1	1	1	1	0	8
Negative	0	0	0	0	0	0	0	0
Overall Responses: Student 2								
	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Totals
Positive	5	0	2	0	1	2	0	10
Negative	3	0	1	1	0	0	0	5

Table 6. Student Responses

attitude towards design-without-make than did Student 2, although Student 2 still had an overall positive response with a positive to negative ratio of 2:1.

Implications and Importance of this study

Design-without-make has many advantages to the modern technology education teacher. It promotes creativity, builds teamwork skills, helps students become more innovative designers, and requires far fewer resources than the traditional design-with-make activities. According to the data collected in this study, the design-without-make pedagogy is just as, if not more, effective than traditional design-with-make methodologies, which makes this pedagogy a new tool for the technology teacher. While design-without-make should not completely replace design-with-make projects in technology education, as technology education moves towards more integration with other subject areas design-without-make may become an even more powerful resource to many.

Recommendations for future research

This study can be used as a precursor to a more in depth design-with-make project or another design-without-make activity. Either may help reiterate and solidify the importance of the design process within students' minds. Future research in this area might focus around:

- Building stronger data sets using larger samples to test pedagogy effectiveness.
- Multiple units of instruction to determine which topics are best taught using design-without-make methodologies.
- Determining which type of teachers this pedagogy is best suited for.

Conclusion

From this research (Thompson, 2009), the authors described how many students in North Carolina are motivated to take technology education because of its hands-on, project-based approach, but they also point out how, these physical artifacts often lack any creativity or innovation on the part of the student, due to teacher designed plans. While these projects are easy to implement and fun for students to complete, often they are evaluated based on the completion of the product and an accompanying portfolio activity. By incorporating design-without-make projects in the place of traditional projects, many of these negatives can be avoided. However, if design-without-make activities are not helping students reach their standardized test score goals, then it is of no use to the modern technology education teacher who is revered or condemned based on those scores.

From this study, it appears that design-without-make is as effective a tool for teaching design fundamentals to students as traditional design-with make activities. According to the data in this study (Thompson, 2009), there was no significant difference in student performance between the groups when run at a 95% confidence interval. Part of this can be explained by Badran (2007), who outlines that co-curricular activities, team work, diversified activities, and strong ties with industry are also important factors for developing creativity in the classroom. Creativity, which helps build intrinsic motivation within students (Spendlove, 2007), is becoming increasingly more important to the future because of the "unlimited horizons" it may open up, providing for ever-broadening, multidisciplinary creativity and innovation (Badran, 2007). Creativity is directly integrated into the Standards for Technological Literacy (STL), developed by the International Technology Education Association (ITEA), and is closely tied to the topics addressed in any technology education classroom. Standards and testing for standards help teachers ensure that students are gaining the intelligence and knowledge base that Sternberg, Reznitskaya, and Jarvin (2007) talk about and, based upon the results of this study, design-without-make is an acceptable approach to teaching technology standards.

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