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TEACHING NURSES CAD: IDENTIFYING DESIGN SOFTWARE LEARNING DIFFERENCES IN A NON-TRADITIONAL USER DEMOGRAPHIC

Stephenson, Katherine Jo; Pickham, David; Aquino Shluzas, Lauren
Stanford University, United States of America

Abstract

This pilot study examines CAD software learning differences between a group of non-technical innovators (clinical nurses) and traditional CAD users (design engineers). This research was motivated by the rapid growth of digital fabrication methods and the proliferation of low cost, semi-professional CAD software, both of which have reduced prototyping barriers for innovators outside of professional design. The study's methodology consisted of (i) a pre-test survey to assess each subject's degree of computer usage and confidence in 3D modeling, (ii) the completion of a CAD tutorial on a laptop, and (iii) an interview to record each participant's impressions of the design experience. Based on a mixed-methods analysis of qualitative and quantitative data, the study showed that the nursing cohort had both the strong motivation and technical ability to learn CAD software. However, their profession enforces a low tolerance for ambiguity or time inefficiency, making the traditional engineering methods of "explore and learn" inappropriate. The output of this study will be used to assemble an extensive experimental curriculum for nurse innovators interested in medical device design.

Keywords: Computer aided design (CAD), Biomedical design, Collaborative design

Contact:
Katherine Jo Stephenson
Stanford University
Mechanical Engineering
United States of America
kstephenson@stanford.edu

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1 INTRODUCTION

In the summer of 2014, we conducted a pilot study to determine the feasibility of introducing digital design tools to a non-technical group of clinical professionals. This study was performed to collect software learning data on medical device users, with the end goal of engaging them in product design or modification *without* the services of a design professional or technician.

1.1 Background

The inspiration for this research came from the growing use of additive manufacturing technologies (also known as "rapid prototyping" or "3D Printing") in clinical practice. According to ASTM Standard F2792 (ASTM, 2012), additive manufacturing is defined as "a process of joining materials to make objects from 3D model data, usually layer upon layer, as opposed to subtractive manufacturing methodologies.".

There have been a large number of papers detailing the use of additive manufacturing in medical cases, with several comprehensive reviews appearing in the last few years (Diaz Lantada and Lafont Morgado, 2012; Giannatsis and Dedoussis, 2009). Potential applications include tangible pre-operative models that allow for careful planning of complex surgeries (Negi et al., 2014), custom implants for large scale bony deformities (Gibbs et al., 2014; Parthasarathy, 2014), "print on demand" devices for small markets and clinical trials (Arrowsmith, 2014) and the fabrication of artificial organs (Murphy and Atala, 2014). With the use of highly skilled multi-disciplinary teams, clear clinical benefits have been observed from using 3D printing in clinical practice. However, while the technology has driven down the direct fabrication costs for custom applications, the cost for the design and technical services remains prohibitively high. In fact, the expense of these services now exceeds the equipment and materials costs (Hopkinson et al., 2006).

A potential solution to this is to follow the lead of the dental field, which is to integrate device manufacturing (and the CAD and fabrication it requires) into the existing clinical practice. "Digital Dentistry" is the use of Computer Aided Drafting (CAD) and Computer Aided Machining (CAM) techniques to rapidly create tooth restorations within the dental office. While it utilizes miniature high-speed CNC mills and blocks of dental ceramic, rather than a 3D printer, it has been a highly effective method of creating relatively low-cost, custom implants for nearly 20 years (Beuer et al., 2008, Van Noort, 2012). It is significant that the successful adoption of the technology into practice did not require dentists to hire engineers, but for their staff to learn technical skills.

Training clinicians in the use of 3D modelling and additive manufacturing poses a unique challenge. The existing additive manufacturing curriculum has been designed with engineers as its primary demographic (Diaz Lantada et al., 2007). In order to effectively train a completely different profession in this material, a new educational framework will need to be developed.

1.2 Study Motivation & Goals

A complete educational framework requires both a "Learning Style" model and a 'Teaching Style" model. According to Felder and Silverman (1988)., a "Learning Style" model "classifies *students* according to where they fit on a number of scales pertaining to the ways they receive and process information" while a "Teaching Style" model "classifies *instructional methods* according to how well they address the proposed learning style components" . While there has been significant research addressing the learning styles of both clinicians (Fleming et al.,1988; Frankel, 2008; Rassool and Rawaf, 2007) and engineers (Felder and Silverman, 1988) within their own fields, as well as investigations into the teaching of engineering curriculum to engineers (Felder et al., 2000), there is little pre-existing research on technical curriculum targeted at the clinical profession. To fill this gap, specifically in the area of 3D modelling and medical additive manufacturing, we had two general research questions:

- In what ways do the learning styles of clinicians differ from those of engineers?
- Will differences in learning styles between clinicians and engineers require changes to existing 3D modeling and additive manufacturing curriculum, in order to effectively teach it to clinicians?

The ultimate goal of developing this "Teaching Model" is to allow practicing clinicians to rapidly gain introductory CAD and 3D Printing skills pertinent to their clinical practice, in a learning format that is intuitive and in-line with their previous learning experiences. By improving clinician education in additive manufacturing, we expect that clinicians will be more likely to adopt the technology into their practices, with less reliance on outsourced technical services. Improving technology adoption by clinicians and reducing its cost will allow for this highly flexible technology to expand beyond research and early trials, where it can supply increased personalization in general clinical practice.

This pilot study was conducted as a first step to move beyond the existing large, but highly segregated, individual bodies of educational knowledge found in both fields. While it was a small study primarily performed as an exploratory exercise, it was one of the first efforts to directly observe and compare clinicians and professional engineers engaging in the same technical learning activity.

2 METHODS

2.1 Study Overview

This exploratory pilot study had two goals:

- Determine if a group of clinicians could acquire new CAD skills with approximately the same level of effort as a group of professional engineers, as measured by their speed and accuracy in completing an introductory software tutorial.
- Observe and document any differences in learning styles and preferences between the two groups to focus future research on areas critical to curriculum development.

We setup the study as a written CAD tutorial, to be completed by the test subjects on a laptop computer. We asked each subject to complete a short survey before completing the tutorial, and interviewed each subject after the tutorial was completed. A member of the research team recorded each session, which ran from thirty to sixty minutes, via a digital camcorder and screen capture software.

2.2 Selecting Key Events and Hypothesizing Differences

Prior to conducting the tutorial session, we selected a number of discrete events that we believed to be indicative of either the level of difficulty the subjects experienced or a particular learning preference.

These indicators were selected from common events that would likely occur in a learning session and that could be readily observed from the recorded data.

1. *Time to Complete Tutorial:* Total recorded time (in minutes) from when the subject opened the binder containing the hardcopy tutorial to when he/she completed the last step of the tutorial.
2. *Requesting Verbal Assistance from Instructor:* The number of discrete, specific requests for information needed to complete the next step in the tutorial.
3. *Requesting Manual Assistance from Instructor:* The number of discrete, specific incidents when the instructor had to take control of the tutorial software and return it to a point where the subject could continue the tutorial.
4. *Returning to Previous Segment of Tutorial:* The number of page flips performed by the subject to return to a previous page in the hardcopy tutorial binder (presumably to refer to earlier information).
5. *Performing Actions Not in Tutorial (Exploratory):* The number of discrete incidents when the subject was observed to complete actions not explicitly dictated by the tutorial.
6. *Offering Verbal Critique of Software, Tutorial, etc.:* The number of discrete instances when the subjects verbally expressed a positive or negative opinion during the tutorial.

We hypothesized that these indicators would differ between the study group (practicing nurses) and a control group (practicing engineers). The events and hypothesized differences between the test and control groups are summarized in Table 1.

Table 1. Key Events & Hypothesized Differences in Event Frequency between Groups

Tracking Event	**Nurses**	**Engineers**
Time to Complete Tutorial	Longer	Shorter
Requesting Verbal Assistance from Instructor	More Often	Less Often
Requesting Manual Assistance from Instructor	More Often	Less Often
Returning to previous segment of Tutorial	More Often	Less Often
Performing Actions not in Tutorial (Exploratory)	Less Often	More Often
Offering Verbal Critique of Software, Tutorial, etc.	Less Often	More Often

2.3 Cohort Details

Practicing nurses were selected as the focus group for this study. Nurses are rarely considered "technical" experts, and yet they regularly fabricate custom solutions from available materials to meet the wide range of challenges they experience while delivering clinical care (Caldwell et al., 2011). Nurses also rely on computers heavily to complete many aspects of their job, with some reporting up to half their work shift being spent on a computer (Kossman and Scheidenhelm, 2008)

We studied a test group of practicing nurses (n=5) and a control group of practicing engineers with previous experience with CAD systems (n=5). The nurses had to be licensed and practicing for at least five years prior to the study. The engineers had to be working professionally for at least five years prior to the study and have prior experience with at least one CAD package.

The nurses were all female, while the engineers consisted of four males and one female. The average ages of subjects (engineers: 44 $\pm$ 12 years, nurses: 48 $\pm$ 5 years) and career lengths (engineers: 13 $\pm$ 1 years, nurses: 20 $\pm$ 7 years) were similar between groups.

2.4 Survey

Prior to completing the tutorial, each subject was asked to complete a one-page paper survey. It consisted of three demographic questions (age, career and gender) and eight questions on technical confidence answered on a seven-point Likert scale. The phrase "this change" refers to the hypothetical modification the subject might have made to a product in question four.

1. How would you describe your experience with computers ("Every day" to "Never")?
2. How would you describe your experience with computer models of 3-D objects ("Every day" to "Never")?
3. How would you describe your experience with 3-D video games ("Every day" to "Never")?
4. Have you ever modified a physical object to improve its function ("Every day" to "Never")?
5. How confident are you that you could describe this change using only words ("I Couldn't" to "Easily")?
6. How confident are you that you could model this change with a physical model words ("I Couldn't" to "Easily")?
7. How confident are you that you could draw a picture illustrating the modification words ("I Couldn't" to "Easily")?
8. How confident are you that you could model this change with a 3-D computer model words ("I Couldn't" to "Easily")?

2.5 Tutorial

We provided tutorial instructions to study participants as a hardcopy colour printout in a three-ring binder. The instructions were similar to other CAD learning texts in the field, with step-by-step instructions interspaced with colour screen shots illustrating what was described by the text (see Figure 1-Study Materials).

In the tutorial, we asked the participants to model and manipulate a simple 5ml syringe barrel and plunger assembly. A physical plastic syringe was placed next to the tutorial binder in the work space for reference. The tutorial was broken into three segments that focused on different modelling skills. The first required opening, viewing and moving the CAD model. The second and third segments covered generating a new part in the model and then defining its geometric relationships with the pre-existing components.

For solid modelling, we selected Fusion360 (AutoDesk, Inc.), a cloud-based solid modelling program that was first released in July of 2013. The recent release date was part of the reason for its selection, since few professional engineers would have experience using it, prior to participating in the study.
The tutorial software was run on a fifteen-inch Hewlett Packard Laptop connected to the internet via a wireless router. The subjects interacted with the laptop via the laptop keyboard and a three button optical wireless mouse. See Figure 2 for an image of the workspace.

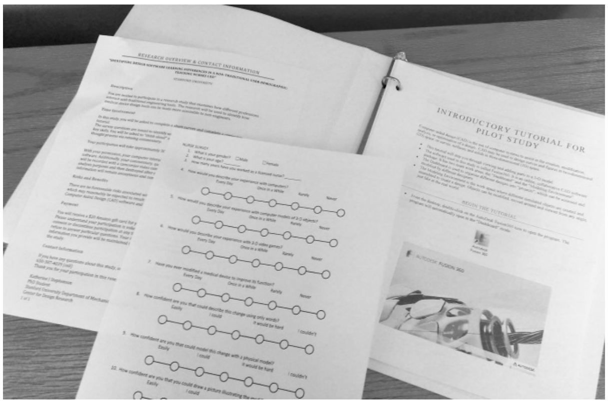

Figure 1. Study Materials

Figure 2. Tutorial Workspace Set-up

2.6 Interview

To capture qualitative data, we asked the test subjects two general, open-ended questions after completing the tutorial.

1. “What are your thoughts, impressions of the tutorial?”
2. “Do you have any questions for me about why we’re studying this?”

2.7 Post Study Processing

After the studies were completed, we collected and processed the various data types for analysis.

- The survey responses were entered into a Microsoft Excel spreadsheet.
- The video of the tutorial segment and the screen capture recording were spliced together using a Picture in Picture (PIP) template in Microsoft Windows Movie Maker 6.0. The two video tracks were synced to simultaneously observe body language and screen activities (see Figure 3).
- The interview portion of the camcorder recording was transcribed word for word into a Microsoft Excel file, with text for the instructor and the test subject placed in separate columns. We placed each verbal statement in its own row, to allow for ease of coding during analysis.

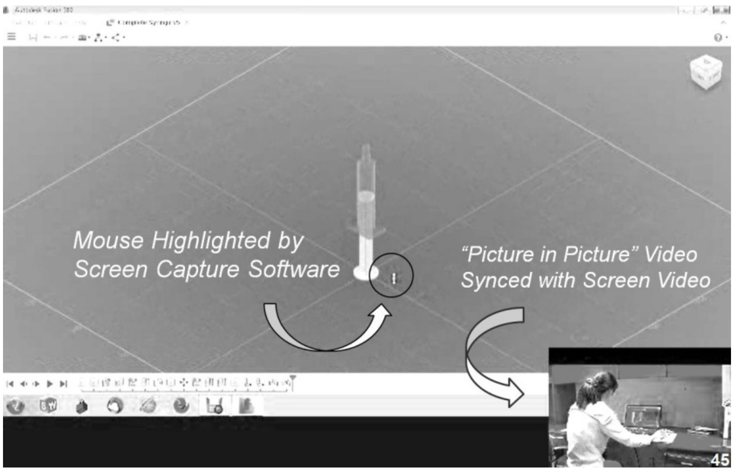

Figure 3. Screen shot of synced video ready for analysis

2.8 Analysis

Following the data collection period, we used a mixed-methods approach to analyse the survey, tutorial, and interview data.

- We calculated the group average Likert score for each question from the survey data
- We then reviewed the processed PIP videos and counted and tallied the key events for each subject. The average event counts were calculated for each group.
- The transcribed interview text underwent both quantitative and qualitative analysis, as discussed in detail below.

For the quantitative analysis, we pasted the subjects' interview responses into separate Microsoft Word Documents and ran them through LIWC (Linguistic Inquiry and Word Count) software by Pennebaker (Pennebaker et al., 2001). The LIWC software analyses text documents word by word and produces a data file that lists the degree to which the text uses positive or negative emotions, self-references, causal words, and eighty other language dimensions.

The Excel transcripts were also analysed using qualitative open coding methods (Charmaz, 2006, Hill et al., 1997) to identify common themes among the groups. We performed an initial line-by-line open coding on a limited number of transcripts to generate thematic categories, which we then applied to all of the transcripts. For a code to be considered significant for either the study or control group, four of the five subjects had to express the coded concept as part of their interview response. The nine concept codes used in the final analysis were grouped into three areas, shown in Table 2.

Table 2. Concept Codes Used in Qualitative Analysis

Learning & Knowledge	Experience & Work	Software Usage
Anxiety over lack of knowledge	Assumes ease improves with experience	Concern over design accuracy
Confident in ability to learn material	Comparison to prior experience	Positive software comment
Exploratory learning	"Forced" to make something work	Negative software comment

3 RESULTS

3.1 Survey Results

Per the data shown in Table 4, both the nurse and engineer cohorts used computers heavily on a daily basis (i.e., the average score for both groups was 6 on a 7-point scale). Yet, the engineers had far more experience with 3-D models of any type, with a group average of 4 (engineers) versus 1 (nurses). From these similarities and differences in computer usage, we can attribute learning differences in this study to CAD experience in particular, rather than general computer expertise.

Of the four design communication methods listed (verbal, illustration, physical prototype and digital modelling), it was only in the 3-D modelling confidence that there was a discernible difference in the groups. As expected, the engineers expressed higher confidence levels in this medium (4 for engineers vs. 1 for nurses). Responses from both groups varied widely, with some nurses expressing greater confidence in their ability to discuss design changes than their engineering counterparts.

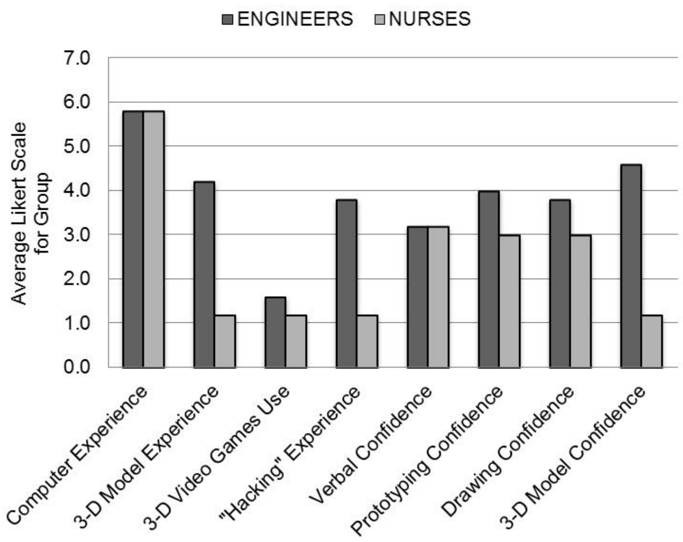

Figure 4. Survey Results

3.2 Tutorial Results

There was no discernible difference between the engineers and the nurses in the time spent on the tutorial (34 $\pm$ 11 min versus 35 $\pm$ 7 min, respectively). However, two of the engineers had to be stopped after one hour, thus failing to complete the tutorial, and another engineer completed the tutorial with the parts misaligned. Of the nurses, only a single subject failed to complete the tutorial. All four nurses who completed the tutorial also completed it correctly.

During the tutorial, the nurses engaged far more with the instructor than did the engineers. They asked more questions, with an average of 6 questions from nurses versus 1 question from engineers. Nurses requested more direct assistance, with an average of 2 requests from nurses and 0 requests from engineers. The engineers, however, referred more often to the written text than did nurses (5 times versus 2 times, respectively) and engaged in more "exploratory" actions that were outside the directions of the tutorial (8 versus 0 actions, respectively).

3.3 Quantitative Word Analysis Results

The automated quantitative analysis revealed that the interview responses were remarkably similar across multiple language dimensions. Engineers used less common terminology, primarily trademark software names and formal CAD terminology than did nurses (93% of the nurse transcripts fell within the software's dictionary, while only 90% of the engineers' words were identified). For the nurses, the interview responses appeared to be less about the software and more about their present actions (15% of the nurses' transcripts consisted of verbs, compared to 12% for the engineers). In regard to words associated with thinking, limited differences were noted (23% versus 21% of the transcripts for nurses vs. engineers, respectively, contained words associated with cognitive processes).

3.4 Qualitative Coding

While the quantitative coding revealed only slight trends, the qualitative coding revealed some distinct differences between the groups.

In the nurse group, there was a definite concern over their lack of knowledge, coupled with a strong drive for accuracy and "rightness". Subject 2, a nurse, described the lack of knowledge as "nerve-wracking." Subject 3 proudly stated, "*I think I am a follow direction sort of person.*" However, in describing their jobs, the nurses repeatedly described freely modifying equipment and software to complete their work tasks. Subject 6 mentioned: "*You create workarounds. Even in software, you create workarounds, and when you find those, those are your saviors.*" She also added the shorter but meaningful statement, *"Duct tape is your friend."*

In the engineering group, the responses were generally framed in reference to their prior experiences with other CAD programs. In contrast to the highly linear, cautious methods of the nurses, the engineers described very open-ended "exploratory" learning styles that did not prioritize task completion. Subject 10 described his learning style as, *"I click around and figure stuff out. I just try to* *do stuff and see what happens."* Subject 7's leading remark was, *"Okay, so the first thing I'm doing is not reading the introduction and going straight in to the tutorial…"* When asked where he might find reference material, Subject 11 responded, *"…well, someone might have a book somewhere that shows me how to use it, but I don't even know where that book is."*

While their approach to the tutorial appeared very different, both groups expressed a high level of confidence in their ability to learn the software program and that using it would become easier with practice. According to one nurse, "*Actually, it's just…like, Excel or a Visio application that takes some time for you to practice and then after you do it more frequently, you become familiar and comfortable with using that tool."*

4 DISCUSSION

While this was a small, exploratory pilot, and as such the results can not be supported statistically, there were a number of clear observations that are supported by prior literature.

It is interesting to note the distinct gender differences between the groups. These groups were actually highly reflective of the professions. According to the Occupational Employment Statistics from the US Bureau of Labour Statistics, 90.1% of registered nurses are female, while 92.8% of mechanical engineers are male (2013). Voyer's paper on spatial thinking skills found that men tended to have slightly better visual-spatial skills than women (Voyer et al., 1995). However, the ability to quickly manipulate the 3D models varied considerably between subjects of both sexes within this study. Future surveys could potentially include a specific aptitude test to better identify this ability within the groups (Sorby and Baartmans, 2000).

The self-reported heavy computer use by both the engineers and nurses is supported by existing literature and the many references to previous experiences mentioned during the interview portion of the study. While not a skill associated with traditional nursing, the ability to adapt and work quickly with a range of software has become a regular part of their profession (Kossman and Scheidenhelm, 2008). In light of this, the nurses' ability to complete the tutorial quickly and accurately is not surprising.

Returning to the group differences illustrated in Figure 4, there were a number of results that ran counter to the initial hypothesis in Table1. While the nurses did request more verbal and manual assistance, the group tutorial times were similar to those of the engineering group. The engineers relied on the written materials far *more* often than the nurses did. What this implies is that one group does not necessarily require more learning assistance than the other, but that there is a definite preference towards how that assistance is conveyed and the amount of time that is considered acceptable before requesting it.

One engineer spent forty minutes repeating the same mistake eight times in a row, completing thirty-two page-flips through the tutorial binder, but did not request assistance. In a recent review of how engineers use information sources, it was found that design engineers can spend as much as 30% of their work day conducting searches for information (Allard et al., 2009). Given the intense time pressure often placed on nurses, a direct request for information is a far more logical problem solving method within their profession.

The nurse's preference for personal interaction is supported by a recent review of clinical web curriculum. Although there have been extensive efforts to create more accessible and lower cost web-based courses, Cook et al. found that there was no significant improvement, and a negative impact in some cases, in education outcome for clinicians when they were trained through internet courses versus a traditional class environment (2008).

4.1 Limitations

As this was an early pilot study used to predict potential challenges in a formal protocol, there are a number of limitations to these findings. The small group sizes for the nurse and engineering cohorts restricted the application of traditional statistical methods. In an effort to reduce potential data biases due to the small sample, we triangulated multiple data sources (tutorial, survey, and interview) to cross-verify and examine data relationships across multiple sources.

4.2 Future Work

We believe that the preliminary data illustrated trends that warrant further investigation. Towards this end, we are proposing a multi-stage research project to develop and validate an additive manufacturing curriculum suitable for practicing clinicians. The proposed stages of the research are as follows:

Stage I: **Knowledge Need finding**: The main goal of this stage will be to determine what current curriculum exists, what preconceptions about the technology will need to be addressed, and what specific types of knowledge will be most critical to include in a 3D modelling curricula.
Stage II: **Course Development**: This stage will cover the development of the course materials, including lectures slides, tutorials, printed materials, etc. Multiple rounds of small focus groups will be used to provide ongoing feedback throughout the process.
Stage III: **Conduct Course**: The curriculum developed will be conducted as a workshop for clinicians, with their experiences and responses recorded. Various assessments to track knowledge acquisition will be included in the workshop design.
Stage IV: **Evaluate applications of 3D Printing in Clinical Practice**: Workshop attendees will be followed for six months following the workshop. Incidents were they engage with 3D Printing as part of their clinical practice will be documented and studied to determine how they may differ from colleagues who did not attend the workshop.

4.3 Conclusions

While the group of clinicians reviewed performed as well as or even better than an engineering control group, they exhibited preferences for different teaching methods and materials. From this early study and prior literature, it can be seen that nurses have the technical ability to learn CAD software. However, their profession enforces a low tolerance for ambiguity or time inefficiency, making the traditional engineering methods of “explore and learn” inappropriate. These early findings provide support for an expanded set of studies needed to transfer an engineering curriculum effectively to this new demographic.

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