Engineering Related Activities Using Digital Fabrication in an Instructional Technology Course For Preservice Elementary Teachers

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Abstract

This study focused on ways in which an instructional technology course featuring engineering related activities using digital fabrication impacted (1) preservice elementary teachers' efficacy beliefs about teaching science, and (2) their attitudes and understanding of effective approaches to integrating technology and digital fabrication into teaching science. The research compared two intervention sections integrating digital fabrication activities, with a third section without digital fabrication activities. Data collected for analysis included the Science Teaching Efficacy Belief Instrument and the preservice elementary teachers' answers to open-response questions about technologies they plan to use in their subsequent teaching. The results indicated the importance of: (1) additional collaboration from educators interested in creating more specific lessons that are designed for their own particular content areas; (2) provision of hardware and software for digital fabrication activities made available to schools; and (3) peer-mentoring of teachers who are not early adopters of innovative technology by other teachers that have become early adopters of digital fabrication activities.

Introduction

Elementary teachers in the United States have reported believing that they lack sufficient science content knowledge, and confidence in teaching science concepts and this issue impacts not only inservice teachers -- preservice elementary teachers have also reported low future science teaching self-efficacy beliefs. In one study, preservice teachers had more negative beliefs towards science and other STEM topics than the middle school students. Teacher beliefs towards STEM topics are relevant because they can sometimes affect pupils' attitudes towards the same STEM topics. Part of the difficulty with increasing students' science achievement develops from the attitudes of both teachers and students towards the subject. Teachers' low self-efficacy for STEM subjects can have lasting impact on students, for example students of these teachers might avoid high school or college STEM courses later in their education.

Recognizing the importance of preservice elementary teachers' efficacy beliefs for teaching science, the Science Teaching Efficacy Belief Instrument (STEBI) was developed by Enoch and Riggs in 1990. Enoch and Riggs created the STEBI based upon Bandura's self-efficacy theory, believing that remediation of low science teaching efficacy beliefs was key to effective elementary teacher preparation programs. Since its creation, the STEBI has been used to measure preservice elementary teachers efficacy beliefs regarding teaching science. One potential avenue for addressing this issue is the use of digital fabrication for supporting science pedagogy.
Digital fabrication enables the design and production of media content that spans several formats from the virtual to the physical -- such as digital models inside a virtual space to physical models made of cardstock or plastic. Two-dimensional fabricators create designs out of materials like cardstock, magnetsheets, and vinyl; three-dimensional fabricators use malleable materials like silicone, playdoh, and chocolate, which then harden into solid objects. Unlike professional design software such as AutoCAD or Adobe Illustrator which require intensive training, student-friendly digital fabrication hardware and software has been designed with the intention of supporting young students and has been used by elementary teachers in STEM education. Research studies focused on digital fabrication have often taken place within extracurricular academic programs that took place during the summer. Another example of a related study took place in a formal classroom with 5th-grade students who had been recognized as advanced in mathematics. The study operated from a modeling-based instruction (MBI) theoretical framework. The MBI framework emphasizes student interactions with models of complex phenomena such as biological ecosystems, and this framework was designed to be interwoven into the regular science curriculum. Student participants demonstrated significant positive gains in correct answers to questions on STEM topics.

The Fab@School Coalition (FSC) was created, consisting of a network of partners representing research universities (University of Virginia, University of North Texas, James Madison University, and Hofstra University), education associations (such as the Society for Information Technology and Teacher Education), and technology corporations (such as hardware company Graphtec, and software companies Aspex and FableVision). The FSC mission is to facilitate integration of the instructional technology digital fabrication into education -- within formal classrooms, informal learning environments, and preservice teacher education.

The FSC has identified four concerns that need addressing for digital fabrication to become a scalable instructional technology. These are: (1) hardware and software, (2) curricula, (3) professional development and preservice teacher education, and (4) assessment. Of these four concerns recognized by the FSC, the present study focused on the education of future elementary teachers. Specifically, this study investigated how an instructional technology course featuring digital fabrication impacted preservice elementary teachers’ efficacy beliefs about teaching science, and their plans to use instructional technology and digital fabrication when teaching science in the future. This study was contextualized within a broader line of research inquiry probing the specific affordances as well as constraints of using digital fabrication within elementary science, technology, engineering, and mathematics (STEM) education. The study analyzed ways in which this intervention affected preservice elementary teachers’ efficacy beliefs about teaching science, and their plans to use instructional technology and digital fabrication to teach science. The research questions for this study were --

1. How does an instructional technology course featuring digital fabrication activities affect preservice elementary teachers' science teaching efficacy beliefs?
2. What are preservice elementary teachers’ strategies to use instructional technology and digital fabrication activities within science teaching in the future?
Methods

This study collected data from 42 preservice elementary teachers enrolled in one of three sections of an undergraduate course, Teaching With Technology, in two consecutive academic semesters. The first two sections (Section A and B) of the course constituted the intervention group, and 25% of the class time (approximately 8 hours of class time, and equivalent outside of class work) was devoted to digital fabrication as an instructional technology. Digital fabrication is an instructional technology that leverages desktop manufacturing software and hardware to translate digital designs into physical objects. Digital fabrication has affordances that might be of benefit within several academic content areas, including elementary mathematics education and elementary science education. The third section (Section C) of the course was a comparison group that utilized the standard course curriculum that did not include digital fabrication activities.

This study employed a convergent parallel mixed-methods design in which both quantitative data and qualitative data were collected, analyzed separately, and then combined during interpretation. Quantitative data from participants who completed both a pre-intervention and a post-intervention Science Teaching Efficacy Belief Instrument (STEBI) survey were analyzed. These analyses were then used as evidence in support of the results posited as a response to research question one about digital fabrication activities affecting preservice elementary teachers' science teaching efficacy beliefs. Participants in the study also answered several open-response questions related to the same constructs of interest as the STEBI at the conclusion of the course, which were analyzed to address research question two about the preservice elementary teachers’ strategies to digital fabrication activities within their science teaching in the future.

Settings and Participants

The setting for this study was the school of education at a medium-sized research university on the east coast of the United States. The setting for this study was three sections of an instructional technology course for preservice elementary teachers taught during the fall 2011 and spring 2012 semester. Two of the sections (Section A and B) featured digital fabrication, and one section (Section C) was used as a comparison group.

Participants in this study were preservice elementary teachers enrolled in one of three sections of a Teaching With Technology course. This course is generally during the junior or senior year of participants’ undergraduate enrollment. Students were informed that participation did not affect their final course grades. The intervention group contained 28 participants total, and the comparison group contained 14 participants.

Students enrolled in Section A and Section B sections participated in the intervention, and devoted approximately 45 minutes each week to developing and using digital fabrication as a strategy for teaching elementary students content from the curriculum, with an emphasis upon science. Students in Section C participated as the
comparison group, and received a general curriculum that did not use digital fabrication activities (and for purposes of equity, were given the option to engage in development of pedagogy using digital fabrication after the course was completed). Data collection for the study began and was completed in approximately eight months.

**Intervention**

Preservice elementary teachers were introduced to digital fabrication as a strategy for teaching content, with an emphasis upon connections to science pedagogy. To support them in this effort they were provided: (1) approximately eight hours of instruction was devoted to the intervention, (2) access to an online repository of digital fabrication based lessons that had already been developed and tested in schools, and (3) additional associated resources including instructional videos and responses to frequently asked questions (available at a website repository with address www.maketolearn.org). Two sections of the course participated as the intervention group, and spent approximately one and a half hours of every other class period devoted to the use of digital fabrication as an instructional technology. Emphasis was placed upon connections to science pedagogy. Participants engaged in activities that utilized affordances of digital fabrication, such as the ability to support the construction of physical models and rapid prototyping of designed objects. The intervention provided pre-service teachers with a hands-on overview of digital fabrication tools and activities applied in a STEM education setting. Participants in the comparison group were taught educational technology without the use of digital fabrication tools or activities.

**Data Collection**

Both quantitative and qualitative data were collected. The study participants completed the Science Teaching Efficacy Belief Instrument (STEBI) at one of the first classes and again at the end of the intervention, and also answered open-response questions at the conclusion of the course.

The STEBI self-efficacy survey instrument focused on science teaching efficacy beliefs. Since its development by Enoch and Riggs (1990), it has been used to measure preservice elementary teachers efficacy beliefs regarding teaching science, as well as expectations regarding student outcomes from teaching science. It was based upon Bandura’s self-efficacy theory, with the understanding that early detection and subsequent remediation of low teaching efficacy in elementary preservice teachers was critical to effective teacher preparation programs. The STEBI contained 25 items, 13 of which are part of the Personal Science Teaching Efficacy (PSTE) subscale, and 12 of which are part of the Science Teaching Outcome Expectancy (STOE) subscale. The PSTEBS is a sub-scale that focuses on the participants’ personal science teaching efficacy beliefs, and the STOES is a sub-scale that focuses on the participants’ beliefs about student outcomes.

Validity and reliability evidence collected by Enoch and Riggs from a sample of 212 preservice elementary teachers indicated that the STEBI was appropriate for obtaining a measure of preservice elementary teachers’ science teaching efficacy beliefs. Reliability
was determined to have a Cronbach's alpha coefficient of 0.90 for the PSTE subscale, and a Cronbach's alpha coefficient of 0.76 for the STOE subscale. An item-total correlation was also determined, and showed values of 0.49 and above for all items on the PSTE subscale, and values of 0.30 and above for all items on the STOE subscale.

Construct validity evidence was determined via consultation with a panel of five science educators, who ensured item agreement and content validation in terms of integrity with the constructs measured, as well as a confirmatory factor analysis which determined the two subscales were modestly correlated (r = 0.46). In 2004, Bleicher re-examined internal validity and reliability for the STEBI with a sample of 290 preservice teachers at the onset of a science methods course. Based upon a factor analysis, it was determined that the two subscales of Personal Science Teaching Efficacy Belief (PSTE) and Science Teaching Outcome Expectancy (STOE) were homogeneous, with loadings equivalent to those originally reported in 1990 by Enochs and Riggs.

Qualitative data was collected via open-ended written response answers supplied in response to questions completed by the study participants. The participants answered questions focused on obtaining a gauge of their plans to use instructional technology when they are elementary classroom teachers. After completing the instructional technology course featuring digital fabrication, participants reported their strategies for how to use instructional technologies in their teaching by answering the question: "Please describe three examples of how you would use technology in your teaching." The answers from participants in the intervention group were analyzed and coded using systematic data analysis. The participants' self-reported answers to this question prompt were tabulated by instructional technology mentioned, and any specific content areas addressed.

**Results**

Quantitative data collected from the STEBI administered at the beginning and conclusion of the intervention was analyzed to determine mean pretest score correct and mean posttest score correct. These averages were used to calculate percentage change as well as standard deviation for participants. These scores were then combined into an overall composite. A dependent (paired) samples t-test, with an assumed p-value of 0.05 and two-tails, was used to determine if any of the findings represent statistically significant results. Additionally, t-test scores for the two sub-scores were calculated using the same assumptions as for the main score.

After course completion, the intervention participants reported significant gains in overall science teaching efficacy beliefs as measured by the STEBI. Science teaching efficacy belief scores went up an average of 5.1% among the 28 preservice elementary teachers in the intervention group. A dependent (paired) samples t-test was used to determine the p-value of this change, and resulted in a calculation of p = 0.004, which based upon an assumed p-value of 0.05 and two-tails, represented a statistically significant result. This result can be compared to the average increase of 3.3% for the comparison group, which when using the same assumptions for a t-test resulted in a calculation of p = 0.073, a
statistically non-significant result. It should be noted that two of the participants in the comparison group were enrolled in a science methods course in the fall 2011 semester. Table 1 below describes the overall results from the science teaching efficacy belief scores, separated into intervention and comparison groups.

Table 1
Results from Science Teaching Efficacy Belief Instrument (Intervention n = 28; comparison n = 14)

<table>
<thead>
<tr>
<th>Group</th>
<th>Pretest score (s.d.)</th>
<th>Posttest score (s.d.)</th>
<th>% change</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intervention</td>
<td>85.9 (6.03)</td>
<td>90.3 (7.39)</td>
<td>5.1%</td>
<td>0.004</td>
</tr>
<tr>
<td>Comparison</td>
<td>86.8 (7.95)</td>
<td>89.7 (7.79)</td>
<td>3.3%</td>
<td>0.073</td>
</tr>
</tbody>
</table>

The two STEBI t-test sub-scores were calculated using the same assumptions as for the main score. The Personal Science Teaching Efficacy Belief Scale (PSTEBS) consisted of 13 of the survey items. Results for the outcomes regarding the PSTEBS sub-score showed statistically significant changes from the pre-intervention to the post-intervention assessment for the intervention group as well as the comparison group. Comparing the participants’ responses showed that the PSTEBS sub-score went up an average of 6.2% among the 28 preservice elementary teachers in the intervention group. A dependent (paired) samples t-test, was used to determine the p-value of this change, and resulted in a calculation of p = 0.008, which based upon an assumed p-value of 0.05 and two-tails, represented a statistically significant result. This result can be compared to the average increase of 5.5% for the comparison group, which when using the same assumptions for a t-test resulted in a calculation of p = 0.014 with statistically significant improvement. Table 2 below describes the overall results from the PSTEBS sub-scale of the STEBI, separated into intervention and comparison groups.

Table 2
Results from PSTEBS Sub-scores of the Science Teaching Efficacy Belief Instrument (Intervention n = 28; comparison n = 14)

<table>
<thead>
<tr>
<th>Group</th>
<th>Pretest score (s.d.)</th>
<th>Posttest score (s.d.)</th>
<th>% change</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intervention</td>
<td>46.6 (4.92)</td>
<td>49.5 (5.22)</td>
<td>6.2%</td>
<td>0.008</td>
</tr>
<tr>
<td>Comparison</td>
<td>47.3 (5.88)</td>
<td>49.9 (5.97)</td>
<td>5.5%</td>
<td>0.014</td>
</tr>
</tbody>
</table>

The Science Teaching Outcome Expectancy (STOE) t-test sub-score of the STEBI was also calculated using the same assumptions as for the main score. The STOE sub-scale consisted of 12 of the survey items from the STEBI. Results for the outcomes regarding
the STOE sub-score showed non-significant changes from the pre-intervention to the post-intervention assessment for the intervention group as well as the comparison group. Comparing the participants' responses showed that the PSTEB sub-score went up an average of 3.7% among the 28 preservice elementary teachers in the intervention group. A dependent (paired) samples t-test, was used to determine the p-value of this change, and resulted in a calculation of \( p = 0.059 \), which based upon an assumed p-value of 0.05 and two-tails, represented a statistically non-significant result. This result can be compared to the average increase of 0.9% for the comparison group, which when using the same assumptions for a t-test resulted in a calculation of \( p = 0.804 \), also a statistically non-significant result. Table 3 below describes the overall results from the STOE sub-scale of the STEBI, separated into intervention and comparison groups.

<table>
<thead>
<tr>
<th>Group</th>
<th>Pretest score (s.d.)</th>
<th>Posttest score (s.d.)</th>
<th>% change</th>
<th>Dependent t-test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intervention</td>
<td>43.1 (3.45)</td>
<td>44.7 (4.60)</td>
<td>3.7%</td>
<td>0.059</td>
</tr>
<tr>
<td>Comparison</td>
<td>42.9 (4.29)</td>
<td>43.3 (4.87)</td>
<td>0.9%</td>
<td>0.804</td>
</tr>
</tbody>
</table>

The qualitative data was used to provide insight into student explanations of ways in which they plan to use instructional technology in their future teaching. Qualitative data was collected via participant responses to an open-ended question that focused on obtaining a gauge of the participants' self-reported plans to use instructional technology in teaching different content areas. Participant outcomes regarding their self-reported intentions to use instructional technology into their future teaching were tabulated according to instructional technology mentioned, and any specific content areas addressed. The top most mentioned instructional technologies were then analyzed for number of students mentioning and percentage mentioning. This results section presents the participants' self-reported plans for using three instructional technologies in their teaching, including the most mentioned instructional technologies as well as number of students mentioning and percentage mentioning. It then presents the participants' self-reported plans for addressing specific content areas using the three instructional technologies they listed. Excerpts from participant answers are presented as examples of the type of responses that were provided.

Participant outcomes regarding self-reported intentions to use instructional technology in future teaching demonstrates that they each could describe a minimum of three instructional technologies that they felt would be valuable in their future teaching. The top five most frequently mentioned instructional technologies in the digital fabrication sections were: interactive whiteboards (25 participants mentioned), video (16), class website (9), interactive online timeline (9), and digital fabrication (8). Additional instructional technologies that were mentioned more than once include: online comic
creation (3 participants mentioned), blogs (3), Google Earth (2), and wikis (2). Instructional technologies that were mentioned once include: spreadsheets, prezi.com, brainpop.com, virtual field trips, laptop computers, interactive-clickers, and hands-on activities. Table 4 below describes the results from the participants' self-reported plans for using instructional technologies in their teaching.

Table 4
Top Results from Participants' Self-reported Plans for Using Instructional Technology into their Teaching (n = 28; each participant listed three technologies)

<table>
<thead>
<tr>
<th>Instructional Technology</th>
<th># Of Participants Mentioning</th>
<th>% Of Participants Mentioning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interactive whiteboards</td>
<td>25</td>
<td>89.2%</td>
</tr>
<tr>
<td>Video</td>
<td>16</td>
<td>57.1%</td>
</tr>
<tr>
<td>Class website</td>
<td>9</td>
<td>32.1%</td>
</tr>
<tr>
<td>Online timeline</td>
<td>9</td>
<td>32.1%</td>
</tr>
<tr>
<td>Digital fabrication</td>
<td>8</td>
<td>28.6%</td>
</tr>
<tr>
<td>Online comic creation</td>
<td>3</td>
<td>10.7%</td>
</tr>
<tr>
<td>Blogs</td>
<td>3</td>
<td>10.7%</td>
</tr>
</tbody>
</table>

Participants' plans to utilize these technologies were occasionally focused on a particular content area, or across multiple content areas some of which were STEM related and some of which were beyond STEM such as history and social studies. Of the 8 participants who mentioned digital fabrication, the specific content areas mentioned were: history (4 participants mentioned), social studies (2), and science, math, engineering, and technology were each mentioned once (engineering and technology were both mentioned by the same participant). Only one participant who discussed digital fabrication did not mention a specific content area -- the lowest participant percentage of unidentified specific content areas of any of the top five mentioned instructional technologies. Table 9 below depicts the content areas specified by the participants in the digital fabrication section.
### Table 9
Content Areas Mentioned for Application of Digital Fabrication (n = 8)

<table>
<thead>
<tr>
<th>Content Areas</th>
<th># Mentioning</th>
<th>% Mentioning</th>
</tr>
</thead>
<tbody>
<tr>
<td>History</td>
<td>4</td>
<td>50.0%</td>
</tr>
<tr>
<td>Social Studies</td>
<td>2</td>
<td>25.0%</td>
</tr>
<tr>
<td>Science</td>
<td>1</td>
<td>12.5%</td>
</tr>
<tr>
<td>Math</td>
<td>1</td>
<td>12.5%</td>
</tr>
<tr>
<td>Engineering*</td>
<td>1</td>
<td>12.5%</td>
</tr>
<tr>
<td>Technology*</td>
<td>1</td>
<td>12.5%</td>
</tr>
<tr>
<td>No specific content area mentioned</td>
<td>1</td>
<td>12.5%</td>
</tr>
</tbody>
</table>

Eight participants (28.6%) discussed plans to use digital fabrication in their teaching. As examples, Participant A focused on the application of digital fabrication to science education:

> I would also use the more physical technologies that we tried, like creating the circuits and making the speakers. This is a way of translating what children learn and putting it into action. In this class, I’ve realized that a student can read about a topic as much as they want, but actually physically experience the topic provides a level of information absorption that simple reading cannot achieve. Students take much more agency about circuits when they actually build one and hold it in their hands, as opposed to just reading about it. I would love to use this technique and idea for many different topics and technologies.

Likewise recognizing the value of hands-on activities, Participant B talked about engagement and students experiencing fun during digital fabrication science activities. But Participant B focused on how digital fabrication supports visualization and engagement in students’ learning process:

> In my science curriculum, I would most definitely replicate the windmill and speaker project we completed in class. I thought this was not only an engaging activity but also very fun and hands on. By creating and manipulating these materials, students can better understand the ways these technologies work and visualize the things they use in their daily lives.

Some students went beyond the STEM fields, and indicated uses for digital fabrication activities to support history and social studies lessons. Similar to the above student who recognized the value of hands-on learning activities in science, Participant C however focused on the use of digital fabrication activities in social studies:
Digital fabricators are a relatively new technology that I cannot wait to use in my classroom. First, it allows students to take ownership of their work. This tool helps develop a sense of agency because while working with digital fabricators, students act as designers, educators, and builders. Second, digital fabricators take a concept and turn it into a reality. Students watch as a miniature world is built right before their eyes.

Participant D differed from Participant C in that Participant D also connected digital fabrication activities with history and social studies teaching but with the addition of recognition of the many connections between technology and real life:

Another way I might use technology in the classroom is through the Diorama Design program we learned and used in Technology class. I found this software very useful for teaching social studies. One way I might use it in teaching is when studying different lifestyles of people. For example, in 2nd grade students learn about three American Indian tribes and are to know the different home styles, food, and resources of each group. I might have students create each type of home using the diorama design to illustrate the differences between peoples.

Discussion

Participants' self-reported gains in science teaching efficacy beliefs after the instructional technology course featuring digital fabrication were statistically significant. But of the eight students discussing digital fabrication in response to research question two, the content areas most mentioned regarding digital fabrication were: history (4 students mentioned) and social studies (2). Science, math, engineering, and technology were each mentioned only once as a content area, with engineering and technology both mentioned by the same participant. The significantly improved teachers’ self-efficacy indicated that they believed that they had developed more robust teaching strategies in science. Nonetheless, our qualitative results indicated that without sufficient supports the teachers are not likely to continue to pursue the use of digital fabrication activities in their science teaching. A possible explanation for this is that the participants having experienced a relatively advanced and innovative educational technology that has not yet been adopted by the majority of elementary teachers, and after the intervention participants feel more confident using standard classroom technologies such as interactive whiteboards.

It is noteworthy that only one out of eight participants who discussed digital fabrication did not mention a specific content area. Of the most mentioned instructional technologies by the participants, digital fabrication had the lowest participant percentage of unidentified specific content areas. One of the reasons for this is that the intervention design did not provide sufficient examples of digital fabrication activities specific to STEM content areas and educational scenarios beyond STEM. These results appear to indicate that while only one of the intervention participants articulated a plan to use digital fabrication as an instructional technology for teaching science, most of those who did mention digital fabrication had at least one specific content area in mind.
These results appear to indicate that research pursuing a similar line of inquiry as the present study might find it challenging to impact preservice elementary teachers plans to prioritize using digital fabrication for teaching science in their future classrooms. Expanding the use of digital fabrication beyond the areas of comfort of the preservice elementary teachers, and into the realm of science and other STEM related areas, is a challenge for future efforts to expand digital fabrication into a larger educational context. The findings from this current study are in agreement with the recognized Fab@School Consortium concerns that need addressing for digital fabrication to become a scalable instructional technology. In particular, the present study highlighted some of the future challenges facing the design and implementation of professional development for preservice elementary teachers if they are to be able to successfully use digital fabrication activities in their classrooms.

Conclusions

There were several limitations to this study that adversely affected the outcomes obtained. The most notable of these limitations were: (1) the small sample size of the comparison group makes comparison to the intervention group difficult -- the intervention had a combined group of 28 participants that enabled analysis of pre-intervention and post-intervention quantitative data to meet the t-test assumption of having a sample size of 20 minimum; (2) despite the use of a comparison group it was challenging to disentangle the impact of the digital fabrication from the impact of the course as a whole -- because the sample size for the comparison group was only 14 participants, the t-test assumption of having a sample size of 20 minimum was not met making analysis of the t-test results from the comparison group problematic; and (3) the intervention might have had a greater impact if it consisted of a larger portion (> 25%) of the overall instructional technology course.

This current study was a continuation of a series of studies focused on the potential educational value of digital fabrication in the K-12 classroom. This study focused upon a population similar to a previous study that also had preservice elementary teachers as participants. The current study builds upon and extends that work. Even with these recognized limitations from the previous paragraph, there were several worthwhile aspects to the research design of this study: (1) the duration of the intervention which was a full semester and had periodic digital fabrication activities which reduced the Hawthorne effect of introducing an innovative technology; (2) the use of both quantitative and qualitative data to investigate preservice teachers’ self-efficacy beliefs which allowed us to investigate digital fabrication activities at both the group and individual level; and (3) the use of a comparison group allowed us to avoid some threats to internal validity.

Our research indicated that the educational implementation of digital fabrication activities are promising, but have considerable further maturation to go before they are scalable with supports. These supports include: additional collaboration from educators interested in this development process of creating more specific lessons that are designed for their own particular content areas – for example some researchers have begun exploring the
use of educational technology to support STEM activities combining math with authentic contexts such as music; provision of hardware and software for digital fabrication activities made available to schools; and peer-mentoring of teachers who are not early adopters of innovative technology by other teachers that have become early adopters of digital fabrication activities.

Future studies might continue to focus on the impact of digital fabrication in K-12 schools, including the upper-elementary classroom. Follow up studies might include a more prolonged exposure to digital fabrication as an instructional technology for supporting science teaching and learning. Further research will continue to focus on the impact of digital fabrication on STEM education. The federal government has undertaken a national initiative to increase focus on effective STEM education, and the present study was designed within this context. Specifically, this study aimed to contribute to the body of research focused upon supporting the development of future science professionals through the development and assessment of science pedagogical practices supported by innovative instructional technologies.

The particular emphasis during the present study was upon science education, but future studies can expand to beyond science education to other STEM fields as well as fields beyond STEM. The design and implementation of instructional technology courses for preservice elementary teachers that feature digital fabrication might, through empirical studies such as this one, demonstrate impacts that justify continued development and assessment. Future studies might also expand beyond the scope of preservice elementary teachers to include inservice elementary teachers, and studies involving K-12 students. Future studies might also study additional variable to teaching self-efficacy, and include focus on achievement, engagement, and other pertinent constructs of interest. This study was undertaken so as contribute to the line of research aimed at improving the education of future STEM professionals in the American workforce.

References


