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INNOVATIVE 3D PRINTING INTEGRATION IN IS EDUCATION: A CASE STUDY OF EXPERIENTIAL LEARNING

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ABSTRACT

Aim/Purpose	The purpose of this paper is to illustrate the integration of emerging technology (ET) integration in the information systems (IS) curriculum.
Background	Modernizing the IS curriculum is consistently needed to meet the demands of the workplace. The IS2020 curriculum model recommends adding emerging technology learning into the IS curriculum. It presents recommendations for IS programs based on demands from education and the workplace.
Methodology	We designed, implemented, and improved a 3D printing assignment that was delivered to sophomore-level and junior-level IS courses with multiple sections. The data was collected over seven semesters. The students were required to complete a survey after completing the printing task.
Contribution	The paper has two contributions: (1) it provides IS educators with a recipe to integrate ET skills and knowledge into their pedagogy, and (2) it opens research opportunities for emerging technology to fill the gap in the IS literature.
Findings	There was a high completion percentage of printing 3D objects. The student learning was enhanced by user engagement and constructivist knowledge creation.
Recommendations for Practitioners	We need to create experiences that can drive deeper thinking about the role of emerging technology. That will grant learners opportunities for reflection on effective organizational use of such technologies.

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Recommendations for Researchers	Future research can benefit from assessing technology integrations through comparative studies. We suggest focusing on assessing success and failure factors and focusing on learner motivation.
Impact on Society	College graduates can benefit from acquiring knowledge and skills in emerging technologies. These graduates can help their employer organizations improve their processes and advance their strategies.
Future Research	Research on assessing technology integration in the IS curriculum should be explored. In addition, researchers should investigate the impact of integration on other disciplines outside of IS.
Keywords	3D printing, emerging technology, IS curriculum, integration

INTRODUCTION

The IS2020 Competency Model (Leidig & Salmela, 2021) template is the latest iteration of the model curriculum for the Information Systems (IS) discipline. It relays the guidelines of the required knowledge, capabilities, and skills for IS graduates: "IS2020 is grounded in the expected requirements of the industry and the needs and perspectives of organizations that employ IS graduates …" (p. 7). The model curriculum is a joint effort between the Association for Computing Machinery (ACM) and the Association for Information Systems (AIS). Similar efforts have been advanced since the 1970s. It presents recommendations for IS programs based on "the demand for education and steers the competencies expected from graduates as they enter the job market and proceed in their professional career" (p. 14).

The curriculum suggested by IS2020 values adding emerging technology learning to IS programs to enhance both the technology and organizational (digital innovation) domains (Leidig & Salmela, 2021; Mitchell, 2022). Thus, the IS domain specifically needs to be more intentional and explicitly deliver emerging technology knowledge to better meet hiring manager expectations (Draus et al., 2022; Sidhu & Kang, 2010). Accordingly, it becomes important to modernize the curriculum by exposing students to ETs (Thomas & Negash, 2023). In turn, developing that knowledge will enable the students to innovate in their respective organizations after graduation.

ETs such as virtual reality (VR), drones, robots, Internet of Things (IoT), and three-dimensional (3D) printing continue to appear, flourish, and change daily life. They bring with them promises of benefits to society and business (Bailey et al., 2019). Of special interest to this project is 3D printing.

3D printing, or additive manufacturing (AM), has been gaining popularity in education and manufacturing for its potential impact on various social and environmental reaches (Loy, 2019). It affords educational institutions a platform for engaging in problem-solving activities. Moreover, the National Science and Technology Council (2022) emphasized the importance of additive manufacturing in its National Strategy for Advance Manufacturing report. The report highlighted the roles AM could play in developing innovative materials and processing technologies and enhancing supply chain interconnections.

The overall project addresses recent calls for IS students to develop ET skills to create business value in business organizations (Milovich et al., 2020). At the center of this work is the notion that information systems students are preparing to support businesses in their "digital innovation" (Leidig & Salmela, 2021, p. 58) or digital transformation efforts (Topi, 2019). Those insights prompted several questions that led to designing the learning experience: How can an emerging technology be effectively integrated into the Information Systems curriculum? How can the learning infrastructure be configured to support learning about an ET? How to design an engaging activity that gauges the technical and managerial learning gained?

Consequently, we designed, developed, and implemented this ET learning assignment based on the IS2020 recommendations. This paper shares the details of the learning experience. We used 3D printing as the ET of choice for the experience. The rationale behind our choice follows.

RATIONALE FOR CHOOSING 3D PRINTING

3D printing has already made an impact on various aspects of business, such as manufacturing and science (Chatzoglou & Michailidou, 2019; Pirjan & Petrosanu, 2013). The importance of 3D printing can be attributed to its versatility. It has the potential to transform many fields, including medicine, manufacturing, architecture, and others (Chatzoglou & Michailidou, 2019). Brooks et al. (2014) echoed that opinion and added, "businesses are realizing the strategic potential for 3D printing to create a competitive advantage using a consumer technology business model" (p. 271). They argued for businesses to integrate 3D printing in support of their processes.

At the same time, 3D printing is still emerging. Rapid technological advances in hardware, the availability of open-source software, and low-cost 3D printers have spread 3D printing to educational institutions (Santos et al., 2019). Integrating 3D printing into the curriculum is helpful in creating the business expertise the workplace seeks (Chun, 2021; Song, 2018). While using 3D printing, learners can develop problem-solving skills by designing and creating products as solutions. Song (2018) acknowledged the increased attention given to 3D printing as an emerging technology in educational settings. They rationalized that integrating 3D printing in an educational technology context is not just about how to use the technology **"but also how technology intersects with pedagogical and content knowledge"** (p. 185). Lupton (2015) claimed that 3D printing offers potential affordances to develop creativity; furthermore, the ability for individuals to produce their own objects represents "democratization" and "knowledge sharing" (p. 1). Hsiao et al. (2019) argued that students learn better with assignments that connect their life experiences and "knowledge gained from their courses" (p. 179).

Chong et al. (2018) used the phenomenon of Industry 4.0 to argue for engineering students to seek modern skills and abilities in preparation for their professional careers. After they conveyed the benefits of 3D printing to businesses, they called for setting up the appropriate learning environments that afford learners opportunities to acquire said competencies. They also advocated collaboration across disciplines to prepare faculty for such integration initiatives. We discuss ETs with a focus on 3D printing in the following Literature Review section.

LITERATURE REVIEW

To design our 3D printing learning activity and address the research gap, we begin by reviewing existing literature concerning the design of effective ET activities. First, we can see a core argument for why ETs should be included. ET learning experiences need to be deliberate and included directly in the focus of teaching (Falloon, 2020). Technology-related learning should be designed to enable students to directly experience a topic. The learning will need to be situated in an appropriate context with personalized experience. Veletsianos (2011) argued that emerging technologies should be used in teaching and learning because of their potentially transformative impact on learner engagement. Improved engagement leads to improved learning and retention (Carlson et al., 2019; Fokides & Lagopati, 2024). Given the large potential for benefit, there is a need to understand how to integrate emerging technology into courses effectively. Students need business context and technical skills with the ETs while having hands-on experiences and reflection (Thomas & Negash, 2023).

The learning experience should provide analytics for feedback and reflection to understand success and failure (Hsiao et al., 2019). The context should be developed to identify its connections to the larger world. In IS education-related studies, we can see existing support for many of these approaches (Alrushiedat & Olfman, 2013; Dalal, 2012; Levy & Hadar, 2010; McLoughlin & Alam, 2014; Rosario & Widmeyer, 2009; Saulnier et al., 2008; Wu et al., 2008).

Hernández-Leo et al. (2019) proposed a teacher-centered framework for learning design with a heavy reliance on analytics. Their concepts of community analytics, design analytics, and learning analytics underscored the importance of incorporating measures of performance, feedback to learners, and feedback concerning technical success. Beyond analytics assessing outcomes and processes, Rolf et al. (2019) suggest assessing the digital competence of learners to match the instruction to learner capabilities and levels. In concert with this idea, Fitzgerald et al. (2018) found that implementation of a personalization approach was challenging but valuable. It could enable students to work at their level of capability but would require access to the analytics/feedback indicated by Hernández-Leo et al. (2019). Similar findings in an online social informatics course implementing hands-on technology experiences underscore the importance of being intentional about pedagogy and enabling learner self-regulation (the ability for the student to get feedback and judge their own product and then use that information to (re)design it) (McLoughlin & Alam, 2014).

Modernizing the IS curriculum is consistently needed to meet the demands of the workplace. Thomas and Negash (2023) used emerging technology in their course design project. They discussed blockchain as the basis for a project-centered learning approach. They rationalized that their proposed design resulted from the need to update the IS curriculum with ET. Their paper presented a template for course design that focused on blockchain as the ET of choice. The template starts with the goal of creating an ET course. It includes a pedagogical ladder, activities, and blockchain lesson plans as examples (lectures, scenarios, and case studies). The authors cited the contributions of the template, including a course design guide, flexibility to accommodate any ET, and varied content.

These studies suggest the importance and challenge of hands-on technology learning as a means of direct experience. They also suggest the application and production of a result within a situated context. Achieving both goals requires hands-on, active learning (Finelli et al., 2018; Papert, 1990). Multiple examples of technology educators identify the learning value of student hands-on technology. For example, Dalal (2012) had students use rapid digital game tools to build computer game prototypes, resulting in higher learning and engagement. Alrushiedat and Olfman (2013) found that creative hands-on activities enable students to create their own learning and become more engaged with deeper comprehension. The key strategies for enabling this learning include an engaged learner seeking knowledge, an interactive learning environment, a problem-solving context, and a facilitated learners' interaction (Gance, 2002; Rueda et al., 2018). Each of these may be challenging to construe at any given time. Hands-on experiences can be related to the larger literature on experiential learning, as one of the objectives of experiential learning is to spur student engagement (Doyle & Chiu, 2023; Fokides & Lagopati, 2024). IS educators seek to motivate the students by creating active learning opportunities, as is the case with ET tasks.

In a high school class, Nemorin and Selwyn (2017) conducted a study on a 3D printing course to investigate the effect of ETs on learning. They acknowledged the appealing nature of implementing the technology in the classroom. They noted that the hands-on nature of the 3D projects/tasks could be exciting, and learners could be enthusiastic about them. They found out that the artifacts that resulted from the design and 3D printing process presented good motivation for the students. However, they questioned the setup for the experience. That had to do with the fact that all of the printing had to pass through the engineer/instructor, who asked the students to email him their design documents. That was an issue because the structure took away from some of the students learning because they did not have a wholesome experience. Hsiao et al. (2019) conducted a similar study with high school students with engineering interests. The researchers sought to assess the usefulness of using 3D printing to support experiential learning strategies (ELS). Their rationale was that 3D printing afforded the learners hands-on practice and a personal learning experience. They believed that 3D printing was helpful to the learners at personal and professional levels. They found that the participants who used 3D printing to complete their tasks were more effective. The main aspect was that these learners connected their printed artifacts to newly acquired knowledge.

Dickson et al. (2021) also conducted an experiment on 3D printing in a K-12 school. They used a middle school classroom to teach production failure. They believed that introducing a new technology and going through the process from setup to production would help students learn about accepting failure as an accepted factor in the workplace. Though we find several examples from high school contexts, we do not see clear examples in higher education, particularly in larger, core classes with non-technical students.

We sought for this project to share a case study of integrating 3D printing to teach information systems. As ETs continue to flourish, the IS curriculum needs to evolve by embracing them. Antonova (2018) argues that businesses should focus on emerging technologies because they are becoming widely accepted, and they will inspire change in business processes. We grounded our work on students engaging in a hands-on learning activity that would result in knowledge creation. That is the essence of constructivism. We discuss it next.

THEORETICAL FRAMEWORK

The nature of experiential learning lends itself to constructivism, a learner-centered theory that builds on personal relevance to drive learning. Personal relevance causes learners to care about a subject and take the initiative to learn it (Doyle & Chiu, 2023; Petrina, 1992). Thus, any activity should be designed with the learner in mind and customized as much as possible to apply to them (Zuga, 1992). This suggests a substantial challenge for deploying an ET activity in a large core class. Such a learning environment can be accomplished by setting up creative assignments with opportunities to assess and receive feedback between phases or iterations (Finelli et al., 2018). Kong and Song (2013) offered a principle-based pedagogical design framework for constructivist learning. They explained that such design focuses “on guiding principles and customizable practices than on predefined tasks and rigid procedures …” (p. E210). They underscore that such a learning approach relies on access to resources to develop skills and share knowledge. The problem-solving context can be implemented by emphasizing knowledge construction and solution development concerning an authentic, open task (Jonassen, 2000). Some underscore the importance of applied authentic learning (Dalal, 2012; McLoughlin & Alam, 2014), active construction of knowledge (Rosario & Widmeyer, 2009), learner-led (Saulnier et al., 2008; Wu et al., 2008) or developing social meaning of learning (Alrushiedat & Olfman, 2013; Levy & Hadar, 2010). Finally, means for learners to see each other’s outputs and interact with faculty or other learning assistants during the activity to facilitate learners’ interaction (Rueda et al., 2018). We apply the principles of constructivism in the design of the 3D printing assignment. We elaborate on its details by sharing our methodology.

METHODOLOGY

We deployed this ET assignment with 3D printing technology in a core class serving more than 1,000 students per semester. The Fall 2021 initial rollout of this activity targeted in-person classes with the option of online students also participating. In total, 11 faculty members (five adjunct, three clinical, and three tenure-track) were teaching in-person sections of the targeted IS Core class. In the following subsections, we discuss the development, implementation, and improvements of the assignment.

There were two main phases to our project. The first was the development pilot, and the second was the rollout. The former included brainstorming and building the infrastructure. The latter included the implementation and evolvement of the assignment. We share details of each in the next two subsections.

INITIAL DEVELOPMENT PILOT PHASE

The Course Coordinator and the 3D Lab Director (one of the authors here) met in Spring 2021 to begin design work. Regarding infrastructure, researchers in a 3D printing lab in another department had studied printers and configurations for 10 years prior. They had already identified one configuration optimized for the highest quality, reliability, and maintainability with the lowest cost. That setup was selected for the initial standard of the ET in order to hold it constant during the development and implementation, and a set of printers was acquired and installed.

The first step for designing the learning was clarifying the goals for the project. As mentioned in the literature review above, this activity had to be a hands-on example of ET. Because we were running the activity in a business school curriculum context, students would need to gain both technical and managerial knowledge. That knowledge would be present if students expressed their confidence in being able to (1) design and complete a print on their own in the future (technical knowledge) and (2) explain the value and related risks of using 3D printing technology if they were asked in the future (managerial knowledge).

With these goals clear, the Lab Director started a process to develop the 3DBrandObject activity (Appendix A). This activity required customization to a student's personal brand (symbol of personal relevance such as name, initials, symbol, etc.) to ensure personal relevance. One faculty member offered her class in Spring 2021 to be the pilot setting. At this point, there were six printers that were not networked yet. So, print files containing the 3D image had to be directly loaded to a single computer. All of this was manual and required technicians (the Lab Director and a volunteer undergraduate student he had trained) to help at every moment during this first test. This process could not scale to the larger target setting. The instructions were given directly and verbally while showing the online TinkerCAD (a web-based software to design 3D printing objects) interface, which is available for free through a web browser, and how to use it. Most of the students were able to design and start printing a personal brand object within that first one-hour session.

The positive results motivated further development. They also clarified some technical issues concerning printer capacity. Average print time depended on object size. Keychain-sized objects could print in 30 minutes or less. This meant that students could potentially have their object within a class period. Having at least one student complete the whole process and be able to show the result served as a motivator for the others. From this pilot, we generated an initial set of written instructions for the activity.

Three weeks later, another faculty member volunteered his junior-level class as a second pilot test. In this test, during May 2021, students followed the written instructions while the Lab Director presented with the undergraduate volunteer student. This was a larger class with about 20 students present. Results were similar, including two students completing their model and being able to show it to others within the class period. We developed videos covering key aspects of the computer-assisted design (CAD) interface as well as slicing issues. Print preparation (slicing) was difficult for students with the full-featured software installed on lab computers. They had to manually set up many technical configuration settings. Additionally, we needed a way to track students' progress to understand overall errors and problems. The TinkerCAD software offered "classrooms" as a tool. We incorporated it into the design at this point. In the Summer semester of 2021, the Lab Director used his capstone class (IS 4880) to help him test and refine the activity before integrating it into the introductory IS course. This class was comprised of 36 students. All of them went through multiple versions of the activity using the instructions for using the web-based software. They iterated several times and used their experience to refine the process. By early July, there was a much-improved version of the instructions, newly formatted to fit onto one page following the standard design for the core class.

Another faculty member volunteered to be a pilot test. This section (IS 2200) was a sophomore-level course, the target course of the ET task. This fourth round of testing tried a different method. Students received digital and printed versions of the instructions, and an undergraduate student presented the activity. Of the students present during that session, all but one were able to design an object and send it to the printer to begin printing. Several students completed it. We noticed that some students were uncertain about the overall requirements of the design. For example, some students were designing elements below the work plane. Another example, a student put letters floating in space detached from the rest of the design. These observations led to a further iteration of the instructions.

INITIAL ROLLOUT PHASE

The main learning test for this study centered on a core course in a Bachelor of Business Administration degree program in a large suburban setting in the Southeastern United States. The university is a large (>47,000 students), low-budget public university. The course was the first Information Systems course business students encountered in their curriculum. Approximately 2,500 take it annually. Most take this course as second-year students, though a portion also take it in their first year. Generally, 900-1000 students take the course in-person modality. The rest are online. For this sample, we selected to focus on the in-person courses. This led to an initial sample population of 972 students in the initial rollout phase in Fall 2021. We collected data most intensively from this cohort and then continued to iterate and collect results data for the following two years.

A final design consideration was feedback from students. The Course Coordinator agreed to deploy a required survey during the activity. That short survey went through several pilot development rounds to ensure brevity and capture key learning progression data around a change in knowledge about 3D printing from both technical and managerial aspects (Appendix B). The finalized design was hosted in a separate survey tool from the LMS so that student input would be anonymized to course instructors. Students submitted a screenshot of the submission confirmation for credit. We shared the student feedback (Appendix C).

We continued our experiment for seven semesters. In the next section, we report on this initial rollout phase and its results. We also share data for the seven-semester duration, the improvements we made, and reflect on what we learned.

RESULTS AND ANALYSIS

The first goal of this study was to design and test an emerging technology hands-on activity using 3D printing and successfully roll it out to a large group of lower-level IS core class students with semi-trained faculty. Success in this case would be indicated by student and faculty satisfaction with the process as well as indications that students successfully completed the process. Figure 1 depicts the process flow and the number of students who progressed through the stages.

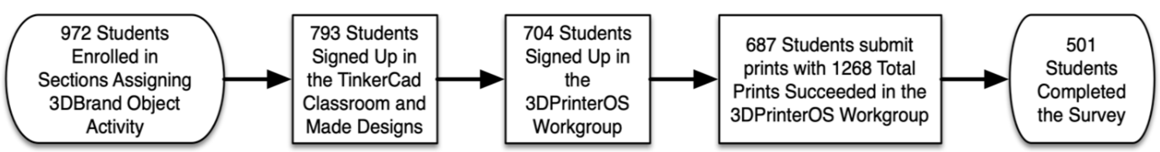

Figure 1. Process flow of 3D brand object activity with flow metrics, Fall 2021

Overall, 793 students began the activity (82% of the 972 enrolled). Of those, 704 (89% of the 793) created accounts in the cloud 3D print management software. Of those, submitted prints were 687 (98% of the 704). Finally, 501 submitted the feedback survey (87% of the 687 or 59% of the initial enrolled population).

Another objective of this study was to enable students without prior 3D printing learning to be successful at learning to use an emerging technology so that they would gain both technical and managerial (conceptual) skills with it in a very short (~1 hour) in-class activity. Success in this goal would be indicated by student satisfaction with the activity (an indicator of building confidence and self-efficacy in learning new technology) as well as survey responses indicating capability gained in technical and managerial skills. Few students had any prior knowledge or experience with 3D printing prior to this activity (440 out of 505 indicated little or no knowledge) (Figure 2).

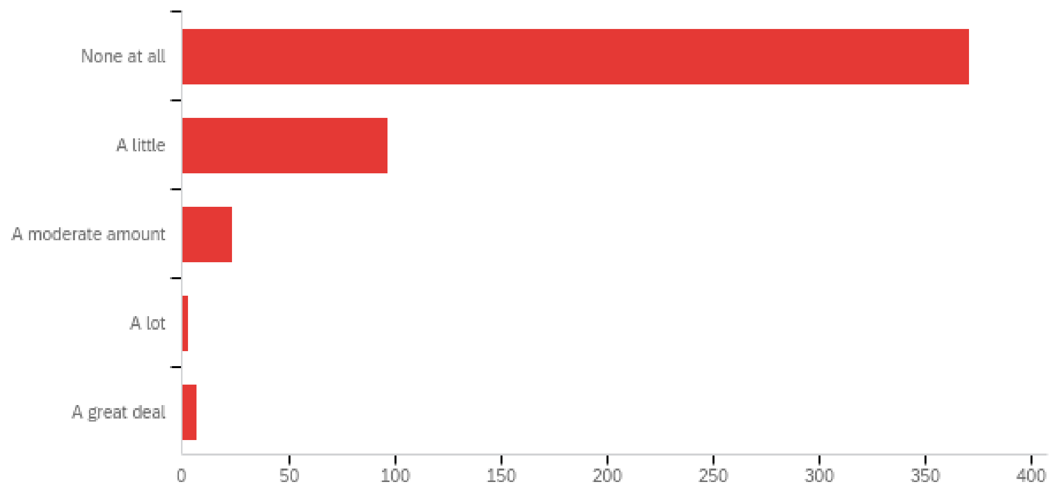

Figure 2. Q1 - 3D experience outside of class

Students received feedback. The online system sent confirmation messages at every stage, including when prints failed or succeeded. Students could then use the online interface to fix and resubmit. Two lab assistants monitored and fixed printers and jobs as they came into the online queue and physical printers. If a print failed, they often logged a failure explanation with suggestions for fixes that were emailed to the job submitter. The print logs held timestamps for prints as well as the specific job details, account email, and expected versus actual print times.

We analyzed the expected versus actual print times. In general, we measured the print speeds and saw that typical actual times exceeded expected by as much as 100%. They were almost never shorter. Failed prints were either shorter than the expected time or much longer. We coded the jobs using this logic. Since we could filter the jobs by user account, we could remove all prints originated by lab staff (these prints were usually tests and designs for special projects, maintenance, and research) and see if the first attempts submitted by other accounts worked (Table 1). We focused on the first print success rate as a good overall measure of how well the design worked, indicating new users succeeding on their first try with this emerging technology.

Table 1. Print log analysis metrics for print jobs Fall 2021 – Fall 2023

Enrollment	2021 FA	2022 SP	2022 SU	2022 FA	2023 SP	2023 SU	2023 FA	Sum Total
In Person	751	667	32	836	610	34	808	3738
Online	357	392	234	398	432	260	394	2467
Total	1108	1059	266	1234	1042	294	1202	6205
Pct Online	32%	37%	88%	32%	41%	88%	33%	
Print Jobs Submitted	1345	869	259	1480	1180	284	1394	6811
Print Job Successes	866	548	190	1085	994	218	1153	5054
Print Job Success Rate	64%	63%	73%	73%	84%	77%	83%	
First Prints (Submitters)	632	412	153	857	639	151	769	3613
First Print Successes	435	298	141	714	582	135	715	3020
First Print Success Rate	69%	72%	92%	83%	91%	89%	93%	

In the first two semesters of scaled rollout of the project, Fall 2021 and Spring 2021, the first print success rate hovered in the lower 60% range (Table 1). We identified several key structural issues. First, orientation to the design and slicing tools was difficult. The students were required to create new accounts and download and install the software. Perhaps not all students could handle that process. We focused on these problems in a large update for Summer 2022. At that time, we eliminated the account/classroom requirement in TinkerCAD. We also created a custom slicing profile for our printers in the embedded slicer in 3D Printer OS (the cloud software) and set it to auto-select once students added the printers to their accounts. We iterated the instructions with various improvements based on the observations we made watching students do the project during the first year. These improvements clarified the sizing of the models, emphasized grouping, and ensured everything touched the platter. That resulted in simplified language and new tutorial videos that were a little shorter. These changes led to significant improvements in first print success over time (92% versus 72% in the prior semester) (Table 1).

The data from Fall 2021 provided a special opportunity for analysis as we had additional account requirements at the time. This enabled us to see the flow of students through the process more clearly and to see all the designs they had made. We manually analyzed that data by scanning through the student designs in the online classroom and associated the accounts with the print logs. In this analysis, we could see repeat attempts at printing the same model and analyze if prints were eventually successful. Of the accounts, 94% were able to print successfully eventually, and 27% showed explicit signs of iteration and extension, going beyond the initial instructions and grading requirements. We took this last detail as a sign of curiosity and self-confidence. We build on our findings in the Discussion section. It highlights the contribution of the experiment and its limitations.

DISCUSSION

3D printing is considered an ET because of its disruptive nature (Leidig & Salmela, 2021; Sigov et al., 2022). ETs present new ways to address needs and create value via their role in DT (Wessel et al., 2021). Regarding 3D printing, this effect applies in various fields and industries (Mohr & Khan, 2015). It is important to note that we learned that some students had used 3D printing, but a very high majority had not.

Development of emerging technology experiences can be integrated with project work in higher-level IS courses. Constructivism theory suggests that sensemaking among stakeholders in an educational setting will create shared meaning over time (Gilakjani et al., 2013; Onuf, 2013). The key is the shared and open experience that allows participation by faculty and students.

Students were able to design something personal, unique, 3D, and digital using new software and then see it become a physical object. Building artifacts usually leads to heightened learning because of the personal relevance (Rosario & Widmeyer, 2009). The scenario situated the task so that it would be broadly applicable to any organization. Making the object required understanding technology-specific concepts like overhangs needing support. It also required solutions like learning how to avoid overhangs so prints would not fail. 3D models need specific settings for heat to accommodate the filament melting and the model sticking to the work plane adequately. These are the elements that make technical learning experiences more impactful (Martín-Páez et al., 2019).

We intended for our project to be useful and helpful to students and teachers alike. The focus was on student learning of an ET to help them in their careers. An important factor in the success of the project was teacher commitment and learning. Next, we discuss how the success of this project can pay off for students and teachers. Such experiences can be successfully designed and integrated into IS courses within short periods following a similar approach to the one presented here (Figure 3).

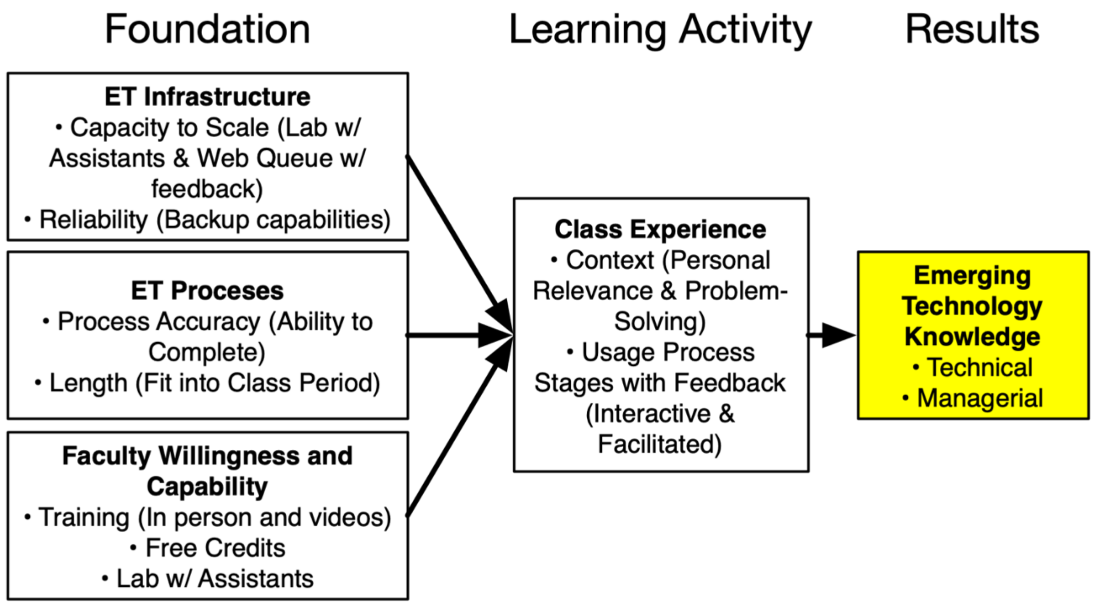

Figure 3. Approach for ET integration into the IS curriculum

CONTRIBUTIONS

Delivering an emerging technology experience at scale in a core class with mostly non-technical majors presented several challenges related to learning theory and practice. We intended to engage the students in an activity that carries personal meaning to them. Among many types of technology learning, students and employers have a significant difference in understanding the importance of emerging technology learning, with students rating lower than employers (Draus et al., 2022). We believe that the large number of completed tasks through the seven semesters indicated solid student satisfaction with the assignment.

A second area of contribution is that we need to create experiences that can drive deeper thinking about the role of emerging technology. That will grant learners opportunities for reflection on effective organizational use of such technologies. Students will be the ones to invent new businesses and applications for these technologies as they enter the workforce. Firsthand experience in creating digital artifacts using an emerging technology develops their understanding of several aspects of this emerging opportunity. For an IS program, we need students to be familiar with the terms, opportunities, and limitations related to technologies so they can assist in the strategic process of refinement, targeting, and implementation of process improvements. The hands-on constructivist experiences in our current case study let them internalize and more fully discover opportunities using their own unique backgrounds and experiences. Theory tells us that they will retain the experience longer and produce more creative applications later due to this approach. Cross-curricular applications with multiple disciplines participating or scaffolding across levels of classes in the curriculum with more advanced ET skills being built later are areas for future research.

LIMITATIONS

Two major limitations are worth noting here. We did not test our learning theory at this point. We simply demonstrated applying it. A full test would need to more carefully demonstrate the learning achieved with stronger measures versus some sort of baseline. This is an interesting space for future research. We were able to capture some measures indicating success, but a larger test is a topic for future research.

CONCLUSION

We designed and assessed a robust learning experience for business students taking a required IS course. The learning experience included a 3D printing assignment that required students to design and print an artifact. Two essential aspects of this experiment were designing/creating the task (instructions, video tutorials, faculty training, etc.) and the physical setup of the 3D printing lab (printers, supplies, lab assistants, etc.). The former required a constructivist approach that presented an experience with personal relevance where learners engage and generate their own knowledge. The latter relied on providing reliable devices and management processes while motivating faculty to participate and deliver the experience.

We tested the assignment over seven semesters that included 6,205 students (in-person and online courses). As 3D printing was new to most students, it was also new to most instructors who taught these course sections. Students usually expect that their teachers have the relevant knowledge to prepare them with learning experiences. Faculty are expected to guide students and answer questions. Thus, we used the same assignment instructions to prepare the faculty. Even when some faculty did not prepare in advance, the design enabled the activity to be delivered successfully. The increasing success rate of first prints (69%, 72%, 92%, 83%, 91%, 89%, 93%) indicated that the improvements in instructions and infrastructure were paying off with a useful learning experience.

Our project contributes to IS education by emphasizing the need for ET integration in the curriculum. We delivered a recipe for how to do it by starting with a supporting infrastructure. Then, design, create, and improve a pedagogy via collaborative efforts from students, faculty, and administrators.

We intended for our experiment to be applied to the integration of any emerging technology and its integration into the curriculum. Educators should always seek to innovate in their pedagogies; emerging technologies can enrich such innovations. Further extensions have begun developing since this first core course activity began. Seven faculty members from other departments have contacted the lab director with an interest in developing activities for their advanced major or elective courses. They value the fact that students got a basic experience in the core class, and they see that as a foundation enabling them to use the technology to do more in these more specialized courses. Future research can benefit from assessing technology integrations through comparative studies. We suggest focusing on assessing success and failure factors and on learner motivation.

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APPENDICES

APPENDIX A - 3D BRAND OBJECT ACTIVITY

Task: Design and print a 3D object that communicates your personal brand.

Learning objective: The student will gain direct, hands-on understanding of the process of designing and building using digital 3D technologies.

Requirements: See below for complete instructions.

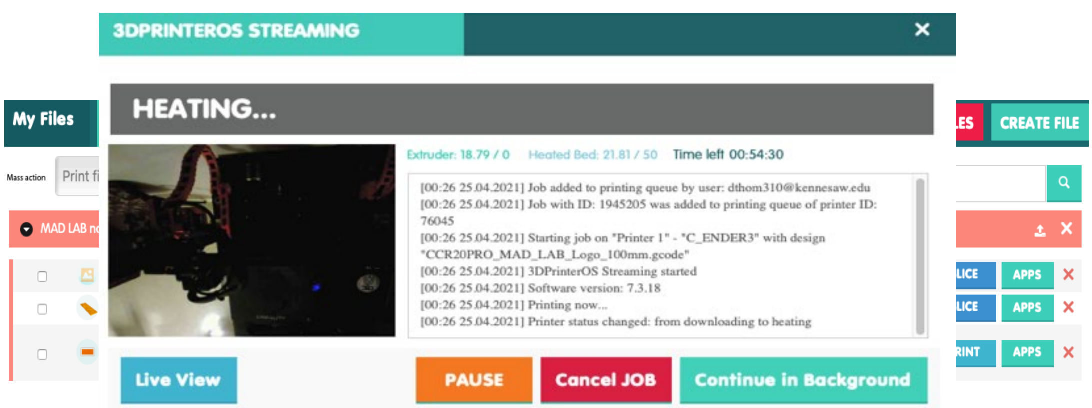
- Make a 3D design. It needs to have at least two letters representing your initials on it somewhere. It could even be a 3D business card of sorts, a name plate, or a key chain to give out.
- It must be no more than 100mm x 50mm x 15mm (4 inches wide x 2 inches long x ½ inch high).
- It must have a flat side on the bottom so that it will easily stick to the printer bed. (More advanced designs need special support to get around this limitation.)

ACTIVITY (COMPLETE INSTRUCTIONS)

1) Design your personal brand object.
    a) Go to https://www.tinkercad.com and create an account using your .EDU email address.
    b) Watch this 15-minute video and follow along to see the whole process: **https://bit.ly/make3dobject**
    c) After you finish the tutorial video, create your digital design.

d) Once you create it, save the file somewhere where you can access it (i.e., email it to yourself if you are borrowing a computer or in a lab) as an STL file. You will see the STL format option when you click export. STL files are standard for 3D designs. "STL" stands for "STereo Lithography (intentional capitalization)."
e) Take a screenshot of the design and save it in a PNG format so that you can show other people what it is and include it with your submission to the printer in step 3.

2) Print your design. Watch this 9-minute video to see the whole process: https://bit.ly/print3Dmodel
Note: in the video it tells you to make your project with the flattest side against the work plane. This is important for your first design to avoid complexity.
   a) Create your account in our 3D printer management system by going to https://cloud.3dprinteros.com/#/registration and registering for an account.
      i) Enter your first name, last name, and KSU email address.
      ii) Choose any password that meETs their requirements.
      iii) Verify your account in email.
      iv) Login and add your local 3D lab printers to your account:
         (1) Click on the Printers tab once you are logged in to the 3D printer OS site. You will see a button to "ADD PRINTER" and three option dots next to it.
         (2) Click on the three option dots.
         (3) Select "Add Workgroup Printers" from the menu.
         (4) Follow the process and use the access code given to you by your professor.
         (5) Once you enter the code, continue.
   b) Click the My Files tab then click the Add Files option. Select the Project button and add a new project name like "Brand Object" then select and upload your STL file.
      i) After uploading your file(s), click SLICE next to your STL file to make a GCODE file (see Figure 1). IMPORTANT: When you see the slicing dialog box, it may have multiple slice options. If so, be sure to select Cloud Slicer. The cloud slicer automatically uses the options available for our Creality CR20Pro printers such as PLA material (we do not have other materials in the basic printers). You may also need to select that printer in a drop-down list. Set the printer nozzle temperature to 210 Celsius and the bed to 60 Celsius. These temperatures seem to print more reliably because they cause better flow and adhesion if the room is cool.



   c) Once you have the GCODE file, click PRINT and select a printer.
      i) Add your class
      ii) And the professor's name in the note. If you are an online-only student and need the object mailed to you, add your name and mailing address in the note. Be aware that the

mailing service is not available at all times of the year and takes special arrangements from your professor.

iii) Click PRINT on that printer if it is available or QUEUE to have it printed once the printer is available. Once you send your print, you will get updates and a view of it printing if your printer has a camera attached (see Figure 2). You can close this window. The printer will complete the print. Pick it up later.

APPENDIX B - STUDENT FEEDBACK SURVEY

Q1. Outside of this class activity, how much have you experienced 3D printing in the past?

None at all (1)
A little (2)
A moderate amount (3)
A lot (4)
A great deal (5)

Q2. How did you feel about this activity?

Loved it (1)
Enjoyed it (2)
Neutral (3)
Did not enjoy it (4)
Hated it (5)

Q3. How easy was it for you to follow the process?

Extremely easy (1)
Somewhat easy (2)
Neither easy nor difficult (3)
Somewhat difficult (4)
Extremely difficult (5)

Q4. How satisfied are you with the technical knowledge you gained from the 3D printing task?

Extremely satisfied (1)
Somewhat satisfied (2)
Neither satisfied nor dissatisfied (3)
Somewhat dissatisfied (4)
Extremely dissatisfied (5)

Q5. Suppose you go to a job interview, and the interviewer asks you to explain some business opportunities related to 3D printing technology. How capable would you be at giving examples?

I would be able to do it easily (1)
I could do it with some uncertainty or difficulty (2)
I would have a lot of trouble (3)
I could not do it (4)

Q6. Did you get your print started or queued in 3D Printer OS by the end of the activity?

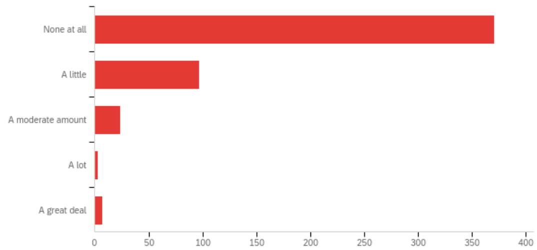
Yes (1)
No (2)

Q7. Do you think that you would be able to do an activity like this on your own in the future?

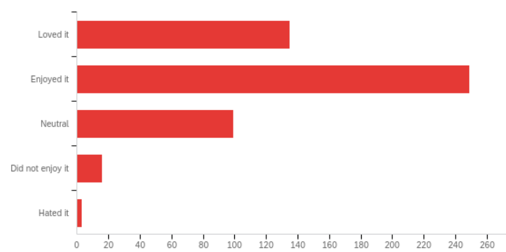
Definitely yes (1)
Probably yes (2)
Might or might not (3)

Probably not (4)
Definitely not (5)

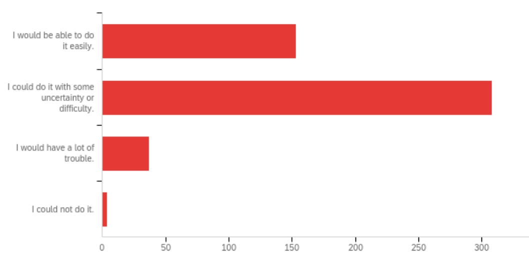
APPENDIX C – STUDENT FEEDBACK SURVEY RESULTS



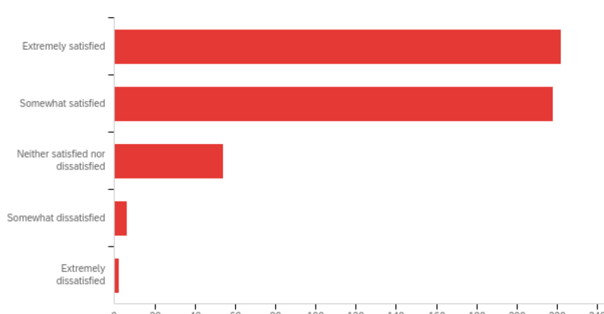
Q1 - 3D Experience outside of class



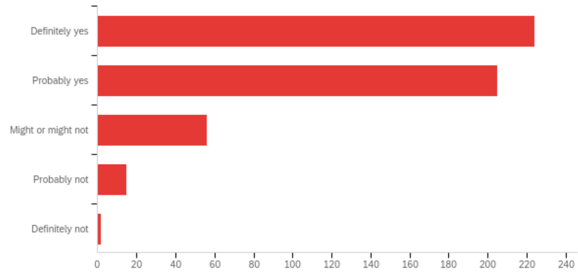
Q2 - Feeling about the activity



Q4 - Technical knowledge gain satisfaction

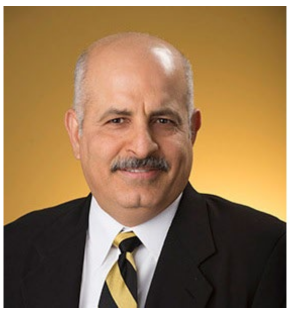


Q5 - Give business examples in an interview



Q7 - Ability to do this on own in future

AUTHORS



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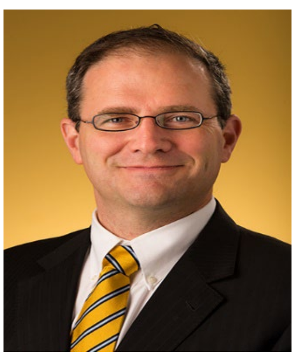

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