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3D PRINTING WITH CRITICAL THINKING AND SYSTEMS DESIGN: AN INNOVATIVE APPROACH TO TASK-BASED LANGUAGE TEACHING IN TECHNICAL COMMUNICATION

Bio data

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Your abstract

Abstract

3D Printing is commonly referred to as a third industrial revolution in manufacturing (Council et al., 2014; Anderson, 2012; Blikstein, 2013), offering a dynamic alternative to traditional manufacturing with its capacity for design innovation, digital fabrication, and data management. Educators who employ 3D Printing initiatives in their language teaching have the opportunity to academically explore new and innovative teaching and learning strategies. This paper discusses 3D Printing as a platform that provides educators with multiple opportunities to explore, invent and implement language teaching ideas while teaching technical communication in an English as a foreign language (EFL) context. The paper takes an instructional approach to explaining how 3D Printing initiatives - including 3D scanning, computer-aided designing, sketchboarding, concept mapping, prototyping with LEGO and maintaining online design feeds - could be successfully included in technical communication pedagogy alongside more traditional genres of document production.
The authors' recent experience at a technical university in Japan suggests that using 3D Printing to teach technical communication in an EFL context is, at graduate level or equivalent, both realistic and feasible if a project-based learning (PBL) approach is taken.

Keywords: Design, Technical Communication, 3D Printing, 3D Scanning, Project-Based Learning (PBL)

Conference paper

Introduction

Technical communication is a method for conveying scientific, engineering or other technical information (Richard, 2005). University educators often approach technical communication pedagogy within a traditional technical writing-based curriculum in a humanities division, where language construction and presentation skills such as document planning, design, organization, translation and editing are the primary focus of instruction. These are, of course, highly important skills for technical communication majors to have.
However, in an English as a foreign language (EFL) context, these skills can be difficult to teach as the students often lack the basic linguistic skills necessary for a typical technical writing-based curriculum. Furthermore, our EFL classroom experience in Japan has shown us that students tend to process linguistic structures in their native language, and then use translation software, online dictionaries and other online language tools to then re-process the linguistic structures in English. Educators in Japanese higher education institutes can and do utilise these electronic language tools in the classroom to try and encourage their students' language acquisition. However, this problem can be further compounded if the students are not highly motivated to use a foreign language and the electronic language tools in themselves do not provide an educational, motivational or skill-building platform from which the students' language acquisition can take off.
One approach to teaching and learning that we have successfully trialled in a Japanese higher education context to address the linguistic and motivational needs of EFL students in a technical communication classroom is project-based learning (PBL). However, our experience has shown us that taking a PBL-based approach necessitates providing the students with engaging 'hook' tasks or activities to grab and sustain their attention. This means the students get involved in *actual* physical and/or online procedural tasks, and learn about technical communication and develop their target language skills while completing the tasks.

The importance of providing *actual* physical and/or online procedural tasks cannot be overemphasised as second and foreign language speakers in Japan are often, in our experience, even more unmotivated to undertake physical or online tasks when given an imaginary scenario rather than a real one. Furthermore, their levels of target language proficiency are frequently low, to the extent that constructing linguistic structures in order to satisfy the requirements of technical documents becomes difficult, unless a practical real-life application context is built around the language writing scenario.

Universities traditionally provide single-disciplinary contexts for studies, whereas modern workplaces can be, and often are, multidisciplinary. This understanding led us to the realization that there was a gap between what we had been teaching our students, and what they often practiced in the workplace after graduation. One way for universities to address this gap is, as we have done, through the use of a PBL pedagogical framework to build partnerships between disciplines, and thus blur the boundaries between technical communication, as taught in traditional humanities divisions, and engineering and computer science divisions (Wojahn et al., 2001).

A potential strategy towards building this partnership is the use of design thinking projects within a PBL framework (Renard, 2014). A PBL framework, both in terms of language acquisition and task completion, ideally includes both convergent thinking (logical and rational) and divergent thinking (imagination and intuition), and also incorporates framing and evolving problems along with solutions that come through iterative practices (Schon, 1983; Steen, 2013). These kinds of problem-solving skills are also typical of design thinking projects.

In the technical communication course discussed in this paper, the group of students tasked with the design thinking project had to brainstorm ideas; discuss potential problems and issues; prototype, revise, and finally deliver physical and digital artifacts; write recommendation and feasibility reports and make online English user manuals.

In developing this task-based language teaching, we drew from Carbonaro et al. (2004) who indicate that problem solving in an EFL-based technical communication course within a PBL framework should be based on processes such as (a) engagement, (b) exploration, (c) investigation, (d) creation, and (e) sharing (Carbonaro et al., 2004). We also drew from Kafai & Resnick's 1996 study on the importance of constructivist learning in today's digital world and students producing artifacts (both physical and digital) that can be shared with a larger audience. Our students worked together toward a shared goal of producing artifacts, following a model of collaborative learning (Laal & Laal, 2012).

It is interesting to note that employing 3D Printing initiatives in language teaching has not yet been explored in the context of teaching technical communication to EFL students. This paper thus discusses an innovative graduate-level technical communication course offered at a technical university in Japan.

Purpose and Research Questions

The graduate-level technical communication course was designed for computer science students who are predominantly second and foreign language users of English.

The course engages the students in active language learning situations (Robinson, 2011) to meet their educational needs through teaching them about 3D Printing and associated procedural instructions design, planning, analysis and implementation. Taking inspiration from Thornburg et al. (2014), it provides the students with hands-on experience in using state-of-the-art software, making oral presentations in English, design writing, workflow scheduling, data management and social organization. The adoption of digital fabrication as an approach to language teaching and learning in the course, while relatively new and still uncommon, is supported by research carried out by Blikstein (2013) into the potentials of digital fabrication in education.

In our study, which was embedded in the course, we addressed the following research

questions:
(1) How do we develop a technical communication course based on project-based and active learning methodology in an EFL context (Dym et al., 2005)?
(2) How can the course content be designed to focus on design and systems thinking and analysis (Dym et al., 2005; McAdams and Dym, 2004)?
(3) In an EFL technical communication classroom situation, are students capable of working in a multi-literacy and distributed work environment? (Cole and Pullen, 2010)
(4) Do the students' choices and performance in the assessment reflect critical thinking, planning, design and implementation as per the assessment mechanism for the course.

The Course

The title of the course is "Technical Writing in Software Engineering". The structure and flow of the course is based on the principles of thinking, teaching and learning in engineering design as outlined by Dym et al., (2005).

This course focuses on the technical documentation of processes leading up to 3D Printing (additive manufacturing) and is offered at the Centre for Language Research in the Department of Computer Science and Engineering at a Japanese technical university. It is a graduate level course offered to a diverse student body made up primarily of second and foreign language users of English. Five students took the course this academic year. They all had an early advanced level of English language proficiency. In addition, they were all proficient and comfortable with system-level operations, which contributed towards their understanding of and engagement with the course tools. However, they had little to no prior experience of writing technical documents in a professional context, and no prior experience with any technical communication or technical writing coursework. Furthermore, the tools explored during the course (e.g., 3D scanners, 3D Printers, CAD design software) were all new to them.

The five students were not only participants in the course, but were also tasked with evaluating it. They thus not only undertook the course assessment, but also provided us with feedback on how the course content, classroom interaction and instructor feedback could be improved, and if a modified version of the course with comparatively less-demanding course goals and assessment could be offered to undergraduate computer science majors at the same technical university in Japan. This "to be designed" undergraduate course was being considered as another course at the university focusing on CAD design and physical LEGO prototyping had been successful at both undergraduate and graduate levels.

The course is carried out in a computer laboratory because the students spend a lot of time using 3D scanners, 3D Printers and CAD design software. It is run on a quarter system: the students meet for eight weeks with approximately 3.5 hours of contact time per week. For the first two weeks, the students are given lectures on technically documenting the processes leading up to 3D Printing. For the remaining six weeks, the classes are run as workshops with the students working together as a group using the supplied tools.

Assignments and Assessment

Table 1 on the following page provides a comprehensive overview of the course goals, tools and assessment mechanism.

Table 1: Goals, Tools and Assessment Mechanism for the Course

Assignments	Grade	Goal	Tools	Assessment
Introduction to technical communication and technical writing	10	1. Understand basic concepts 2. Technical writing in groups 3. How to design tables and graphs from audio-visual information 4. Be able to narrate the broader purpose of the course, and creatively think about the course and the broad understanding of topics in the field. 5. Understand why technical writing is important? 6. Reflect on why 3D Printing is important in computer science?	▪ Free writing ▪ Instructional videos.	1. Ability to write freely 2. Construct grammatically correct sentences 3. Ability to think creatively. 4. Reasonable logic in the arguments.
Designing a user manual for a 3D design app	10	1. Understand how to write procedural information in a systematic way 2. Research and understand how a system or interface functions. 3. Ability to understand the structure and function of a software using Sketch board and concept mapping software	▪ Manual templates and examples ▪ Google Sites ▪ IHMC Concept Mapping software ▪ Sketchboard software	1. Identify the most important structures and functions that defines the software 2. Write clear sequential steps based on the actual procedure or online action. 3. Be able to use the concept mapping and sketchboading software successfully. 4. Ability to design a reasonably acceptable Google Sites online user manual.
Designing an online user manual outlining all the procedures for 3D Printing	50	1. Be able to research all the basics about 3D Printing, 3D scanning, web and product design. 2. Be able to complete all the processes leading up to the 3D Printing, including scanning, 3D Design, LEGO prototyping using 3D software, besides concept mapping. 3. Be able to document the procedures in the online user manual and design a technical presentation explaining the process and outcome.	▪ 3D scanners (iSense and Sense) ▪ Autodesk 123D Design and Make ▪ Tinkercad ▪ BuildwithChrome ▪ Google Drive ▪ LEGO Toolkit ▪ IHMC Concept Map ▪ Sketchboarding ▪ Cubify Print ▪ 123D Catch ▪ iSense app ▪ Google Sites	1. Understand the steps and sequences leading up to 3D Printing 2. Understand the basics of web design 3. Ability to use the tools such as 3D scanners, 3D Printers, and the CAD software. 4. Class observation showing adequate group discussion 5. Ability to write logically and grammatically correct sentences.
Write about the concepts in Interaction and Experience design	15	1. Understand what is interaction design, and standard design processes. 2. Apply the concepts in relation to 3D Printing	▪ Lecture notes and references journal articles on interaction design and experience design	1. Answer the open-ended questions with critical reasoning. 2. Be able to connect the general design principles to the processes leading up to 3D Printing.
Understand how usability techniques could be used for researching 3D Printing	15	1. Understand the basics of website analysis with usability techniques 2. How to research 3D Printing as a topic with survey design?	▪ 3D Printing and Design websites ▪ Lecture notes on usability testing methods ▪ Surveymonkey website	1. Answer website analysis questions with reasonable efficiency. - Answers show critical reasoning, knowledge about web design, and awareness of 3D Printing topics and design issues. 2. Grammatically accurate responses.

Results and Discussion

The five graduate students who participated in the course, and acted as course evaluators, had the maturity and interpersonal skills to be able to work in a learner-centered PBL environment. They used mutual consultation mechanisms such as the brainstorming of concepts, and the questioning of other group members and the instructor, about possible ways forward, how to apply the tools, the design processes, the documentation processes, the design iterations and the prototyping of ideas. Their Google Sites webpage also revealed that they implemented their ideas into practice with reasonable efficiency.

This is not to suggest that there was not room for improvement, particularly in the collaborative Google Docs-based writing process. During this process, the group members participated randomly, and the changes and updates (logs) made by one group member were not always consulted by the other group members before subsequent inputs and updates.

In addition, some students took the lead when the group was designing the virtual and physical prototypes, using the 3D scanners and 3D Printers and during the web design process, while the others simply observed and encouraged their partners' work by providing ideas. This was despite each student being allocated specific responsibility for (1) Design research (2) Using the apps (3) Using the 3D scanner (4) Using the CAD software or (5) Using the 3D Printer.

The students practiced designing and upgrading multiple products following their 3D scanning in the computer laboratory. They spent a lot of time recalibrating the 3D scanner for objects with different shapes and sizes. However, their performance and efficiency with the 3D scanner did improve over time.

The documentation process in Google Sites was also revealing as the students had to make notes of all the procedures related to the 3D printing in advance of performing them, and then take associated screenshots of the procedures as they were being performed. Their performance showed that they were able to do the following: (1) construct logical arguments and (2) write about a sequence of activities in a way that was understandable and usable. At the sentence level the text made sense, and the navigation links were appropriate and represented the logical sequence of task completion. However, the students lacked the necessary skills to put up a website that was visually appealing. For example, the organization of the text, the use of free space, the layout of the website and the text-graphics coordination all needed improvement. Also, the group did not seem to fully grasp the importance of proofreading and attention to detail before sharing the website with a larger audience.

Conclusion

Classroom interaction and observation showed that the students' competence at technical writing improved through writing practice, and that their ability to argue and reason improved through group discussions and exposure to different online and offline tools. The students reported enjoying the opportunity to explore new tools, particularly without the pressure of being in a typical classroom environment (the course took place in a computer laboratory rather than a traditional classroom with rows of desks facing the instructor and the students were allowed to consume food and drink).

As earlier mentioned, it is hoped that a modified version of the course might be offered to undergraduate computer science majors at the same technical university in Japan. However, instructor observation and feedback from the students suggests that this will be challenging as the undergraduate students' English language proficiency, and ability to think and write logically and clearly, are generally comparatively lower.

In conclusion, this study suggests that university instructors who are considering employing 3D Printing with critical thinking and systems design in their langauge teaching have to be realistic about their students' English language proficiency. In addition, in a technical university instructors can expect computer science students at graduate level to have some basic competence in technical writing, and understand about procedural design. However, this might not be the case at undergraduate level or in the liberal arts division of a non-technical university.

Further research is thus needed, particularly on how liberal arts divisions and engineering/computer science divisions could coordinate and build interdependency to offer EFL courses employing 3D Printing-based initiatives within a PBL framework. The use of 3D Printing with critical thinking and systems design in EFL courses at higher education level is still underutilized. However, the authors hope that this paper might encourage educators to consider how they might embed it into their learning programs.

CALL in Context

This paper outlines how 3D printing as a platform provides us with numerous opportunities to explore, invent and implement project-based learning (PBL) as part of technical communication coursework offered in an English as foreign language (EFL) context. In doing this, it highlights, first, context topics such as digital literacies and multiliteracies and, second, specialized domains such 3D Printing-related documentation, design and manufacturing processes for EFL learners.

IMPACT OF CONTEXT:

1. The paper addresses the impact of the local context of the learner, with discussion of an assessment in a technical communication classroom that offers a context-dependent enrichment and personalization of the learning process.

In this context, we discuss a variety of concepts and related pedagogical models. 3D Printing is widely referred to as a new or third industrial revolution (Council et al., 2014; Anderson, 2012; Blikstein, 2013). And, 3D Printing initiatives using PBL in the classroom afford new opportunities for educators to engage students in active language learning situations utilising technological applications and document production.

The paper presents an outline of how a technical communication course adopted the constructivist principles of active learning, and critical and systems thinking (Bean, 2011; Dym et al., 2005), using pedagogical tools such as 3D printers (Thornburg et al., 2014) in a PBL environment. The study suggests how 3D printing-based practices, including 3D scanning, computer-aided design, sketch boarding and concept mapping, prototyping with LEGO, maintaining online design feeds, slicing and online design for 3D printing and documentation can be successfully included in technical communication pedagogy.

2. The study further considers the role of the local context of the learner using classroom observation and assessment data about the extent to which 3D printing technology contributes to contextualization of the learning process. The study highlights an innovative learning environment where language learning is embedded in the local action context.

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