Making English Speakers: Makerspaces as Constructivist Language Environments[1]

Wade Alley[2], Universidad Panamericana, Guadalajara, Jalisco, Mexico

Abstract

A makerspace is a constructivist learning environment (CLE) where learning takes place by creating objects. This paper describes a makerspace applied to second language learning in a university context. The course design and operation, along with its results were analyzed based on activity theory. The results at the end of the course revealed that students improved or maintained their language skill level on a par with their counterparts in traditional English classes.

Resumen

Un *makerspace* (espacio de creador) es un entorno de aprendizaje constructivista (CLE) donde el aprendizaje tiene lugar mediante la creación de objetos. Este artículo describe un *makerspace* aplicado al aprendizaje de una segunda lengua en un contexto universitario. El diseño y la operación del curso, junto con sus resultados, se analizaron con base en la teoría de la actividad. Los resultados al final del curso revelaron que los estudiantes mejoraron o mantuvieron su nivel de habilidad lingüística a la par con sus homólogos en las clases de inglés tradicionales.

Introduction

The makers movement that has taken hold in the United States and around the world over the last decade presents itself as a democratization of fabrication, and an opportunity for people to learn, innovate, and construct whatever they can imagine. It is called a movement due to the growth of Makers Faires, and the burgeoning hobby area known as DIY (or Do It Yourself). One of the most appealing aspects of the maker movement can be found in the community of learning and shared knowledge or experience that people in the DIY community enjoy. What has made turned the community into a viable movement are the same learning elements constructivists have talked about for years, and that language teaching professionals have sought to implement in their classrooms, namely: to build a community of learning that thrives on motivated learners helping each other to solve problems while at the same time interacting with others and solving problems through the use of a target language. The Maker Movement Manifesto lists several requirements for makers to follow, among them are: make, share, give and learn (Hatch, 2013).

To an educator, the maker movement and the makerspaces that have followed might resemble a constructivist learning environment (CLE), that is a space (real or theoretical) where learners are presented "with an interesting, relevant, and engaging ill-structured problem or project to conduct" (Jonassen & Rohrer-Murphy, 1999, p. 69). This is, coincidentally the same definition used to discuss problem-based learning environments (Ram, Ram, & Sprague, 2016). Because activity theory forms the basis of our analysis of the maker course, our understanding of how it works will best be served by referring to the CLE. In the maker community, real, non-theoretical CLE's grow organically, often times with several of them under one roof of a makerspace. In these areas the work of the Vygotsky Circle is made visible and themes such as sociocultural theory, activity theory, and the zone of proximal development are easily observed. Furthermore, the benefits derived from experiential learning and situated learning are readily visible in the maker community and such opportunities to learn allow the community to thrive. How, then, might the same idea, that of building a maker community among language students benefit their language skills, while at the same time providing them with valuable knowledge for their future careers? How might it be done economically, and, if successful, shared to benefit even remote or underfunded communities? This article discusses the results of an experimental English as a foreign language (EFL) class that was based on the tenets of the makers movement, and that took full advantage of the basic concepts of the CLE. The course design results will then be analyzed according to activity theory, while the generally positive student results and reproducibility of the experiment will be analyzed from an experiential learning viewpoint.

The Maker Movement

At the time of this action research and continuing to the time of revisions there has been little, if any research on the maker movement as a context for language instruction. Where the idea of a 'makerspace'

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[2] walley@up.edu.mx

or 'fab lab' do most often seem to coincide with education are in technical school settings, or in after-school programs in urban environments, and mainly in the United States. Because the course was not taught as a pure language course, but as a vocational technical course with English as the language of instruction, the reviewed literature was restricted mainly to works concerning constructivist learning and constructivist learning environments, activity theory, and situated learning. A makerspace, by the way, is nothing more than a constructivist learning environment. For activity theory, I relied heavily on the work of Engeström (2001). I also relied on the seminal work of Jean Lave and Etienne Wenger (1991) for their research in situated learning. Though I am possibly presenting an over-simplification of their work, Lave and Wenger (1991) posited that learning occurs best in the context where that learning will be applied. An apprentice learns better on the job than with a master craftsman in a classroom, for example. Because a makerspace is a constructivist learning environment, Lev Vygotsky naturally comes to mind when researching constructivism, but for this work, more task-specific interpretations of his work proved helpful. Among the more helpful works were those by Donato (2000) about Sociocultural theory and Second Language Acquisition. Donato's findings were particularly helpful to explain the community the students might experience in their future careers and how that might be leveraged for educational purposes. No less important to interpreting the value of realism in the classroom community was Lantolf (2000) who did similar and valuable research in sociocultural theory. Experiential learning can result from problem- and project-based learning, and in this course, that was no exception. I relied on the work of Kolb (1984) for a deeper understanding of how experiential learning took place in the course. Finally, it is important to clarify that the English for Makers course was not a CLIL course, nor was it an English language course in the traditional sense. For those reasons, works about CLIL were not consulted, nor was extensive research done about problem-based learning. It was felt that much greater insight might be gained by reviewing the literature for the factors that became directly evident as the course progressed.

The course

English for Makers was designed as an experimental course that would involve students of engineering at Universidad Panamericana a small, private university in Guadalajara, Mexico.

Course participants

Eight students from the different course tracks of the engineering program volunteered to take part in the semester-long course that ran for 18 weeks in the spring semester of 2016. Comprising all of the career tracks of the department, students ranged in age from 19 to 23, and three participants were female. An additional participant was a member of university's technology and education staff. None of the participants had been students in the university's English language program prior to this course.

Additionally, two students from the mechatronics engineering career field volunteered to participate as assistants to the professor and were required to use English at all times. In exchange, the students earned their required social service work hours. The assistants both had excellent levels of English and had already completed the required coursework in English. Additionally, the assistants were known and well-regarded by the students in the course. Students were also made aware of the experimental nature of the course and that they ran the risk that their English might not improve as a result of taking the course. They were also informed of the much larger extramural experiment behind the course.

Jalisco, Mexico has a persistent shortage of English language teaching professionals. Similarly, the uneven distribution of financial resources precludes expensive materials, extensive instructor training, or anything that could be a heavy burden on school or local internet infrastructure. The substance of the English for Makers course was constructed with the idea that a school that might have a shortage of financial or professional assets might be able to enlist the help of an English teacher to help teach a science course, or that someone in the STEM teaching area might chip in to help with the teaching of English. The material should still be useful in the hands of a more mature student or community service volunteer who might have recently returned from living in the U.S. or Canada. The latter scenario is certainly within the realm of possibility in Mexico.

The author of this article served as instructional designer and professor for the course and had no experience with electronics, and, with the exception of a few years' stint in the military as a photographer and laboratory technician, very little experience in a scientific setting. The instructor also had very little experience with the maker community. The experience that the instructor would bring to bear was his language teaching skill set. As part of the instructor's role as a mediator/participant, the professor had to make things, just as the student did, and limit his speaking time in front of the class to under ten minutes per two-hour session. Finally, the discrepancy between the perceived necessary level of expertise in at least half the subject matter was intentional as it formed the basis of the experimental aspects of the makers course.

Course requirements

The course requirements were simple. In each six-week portion of the class, students had to create a useful or entertaining object, machine, or project using Arduino controller circuit boards (More on the technical and instructional materials used is forthcoming). Sixty percent of a student's grade for each of the three portions of the semester was based on whether or not the product the students made during their class time actually functioned. The other 40 percent of the student's grade were the assessment of the student's presentation of their project, a video explanation of their product, and detailed instructions on how to replicate the design. The platform for delivery of the content was optional, with the exception that the detailed instructions would have to be in an interactive PDF format. This format was chosen to test whether the interactive PDF's might be later used 'in the field' as a content delivery system. Students would also be required to take a mock TOEIC reading exam at the beginning and end of the course to measure any progress that they might have made in the English language. Class was held once a week on Friday afternoons from 3:30 to 7:30 PM. Class time was devoted to researching and finding a project of the student's choosing as well as build time. The exceptions to the schedule were 1-2 hours devoted each week to basic tasks such as learning how to use the Arduino IDE (Integrated Development Environment), a workshop in 3D printing, and a course on Adobe creative cloud programs, among other topics. One particularly fruitful topic was learning reverse engineering. One week of instruction early on in the semester was dedicated to disassembling cheap household appliances to evaluate design, functionality, and longevity. The task gave the students an opportunity to learn new vocabulary as well as to practice using the software needed to deliver their assignments.

In addition to the completed project, the final forty percent of the required work was assessed accordingly:

- 10 percent: Completion of work: all required items were complete, nothing missing.
- 15 percent: Clarity of instructions. Could someone else with little experience, say another student from the following semester, follow their instructions and replicate the object?
- 15 percent: Grammar and Structure (in the first and final portion of the course, student scores on the mock TOEIC reading exam would count toward their grammar/structure scores.)

Student attendance policies are set by the university and therefore not counted as part of the final assessment during each third of the semester. Similarly, the instructor made no explicit demands that the course participants use only English and did not count this as part of the course assessment, either.

Materials used in the course

Based on cursory research, but more extensive interviews with people involved in the maker community, the Arduino microcontroller board and prototyping boards (these are used to work with motors and other specialized devices) were chosen as the basis for all student projects. The boards use the C++ programming language which requires the use of English. The university language department bore the cost of these materials. Other material such as LED' s, jumper wires for making circuits and breadboards for building more complex material were provided at the instructor's expense, while others were donated by course participants and the student assistants. The Arduino boards are not expensive; however they do vary in price depending on manufacturer and location of manufacture. The boards are open-source and anyone can manufacture and sell them, and as an added feature, the basic package of instructions and programming are all on a Creative Commons licensed website. The students used the university's Adobe software to make the PDF's, and a small video studio to make their instructional videos. There were no specialized engineering lab spaces made available to the English department for this course, and students had to move the desks and chairs of a standard classroom when necessary to suit whatever they might be making or doing. Only on a few occasions were they allowed to use the engineering department's specialized workshops for soldering, laser cutting, etc. The inexpensive household appliances were supplied by the instructor as well as some cameras for documentation of student work in finer detail.

Finally, in lieu of a textbook, the website *Instructables* (www.instructables.com) was designated as the course project resource. The site publishes everything under a Creative Commons license that requires redistribution and modification be done for free while attributing the original material to the original author.

The maker community thrives on improvement and adaptation, so this sort of license provides easy adaptability at no cost or royalties. This also had the added benefit that students would have to familiarize themselves with Creative Commons and very basic, but nonetheless important copyright law. The *Instructables* site became so much more than the *de facto* textbook for the course. It was one of those happy accidents of language instructional material in that the site provided seemingly boundless opportunities for students to learn, not only about building circuits, but also about solving what appear to be hopelessly intractable problems by relying on the learning community around them.

Students were required to find their projects on the *Instructables* site. The instructor purchased a site-wide membership in order to download complete illustrated instructions for the students. In general, the instructions are serviceable though geared to more technically oriented native speakers of English. On the one hand, it meant students would have to learn the vocabulary of the maker community and deal with a lot of expressions they had never encountered. They also had to contend with poorly written instructions. Makers generally are very good at building things though not necessarily skilled at technical writing. The contributions at the website are all from skilled maker amateurs with varying degrees of clarity and accuracy, and there is no guarantee that the author is a skilled builder or writer of technical English. As students worked on their project, they began to rely more and more heavily on their student peers and their instructor for help. Because of the instructor's lack of knowledge on the subject, and the students' insufficient English vocabulary, the participants turned to Google for answers when neither the assistants nor the professor could provide a workable solution to their difficulty. Because the original problem was in English, the students would be compelled to word their Google search using English, particularly if they were not sure of the required concepts. Students also turned to Google in Spanish when the problem became too difficult, or to Google translator when the problem was unclear. Remember, the goal was to build a complete and functioning project. No mention or obligation was made on how to accomplish that. As the end of first part of the semester approached, student projects began to take shape. Students had made it each step along the way, and as they saw the projects take shape their confidence grew. Then it came time to program the Arduino so that the device would function as advertised.

Generally, in *Instructables*' projects, the object or device is constructed first. Programming of the Arduino and testing of the complete program take place in the very last part of the project build. What students discovered was that the programming included in the project package was often-times obsolete, incomplete, incompatible or, in more than one instance, the wrong set of code for the device. Only occasionally throughout the course did a student's *Instructable* project work the very first time. One unintended benefit of these poorly written instructions was that students had to become proactive and creative users of the target language. When the programming phase of the projects began, students relied heavily on their fellow builders first, for help, and then on their student assistants and the professor for extra help or suggestions. Failing that, this maker community then decided their best course of action might be to find an English-speaking computer programming faculty member to guide them. Sometimes the programming was so poorly written that their expert couldn't help at all. Some students ended up having to learn aspects of the C++ language very quickly via YouTube and Google or via the many Arduino chat rooms, message boards, and programming sites on the web. Because the errors they encountered were based in English, students had to use and stretch their language skills to resolve those problems. These experiences weren't lost on the students. They took extra care in the following weeks to thoroughly read instructions and programming before settling in to make their next project. This however was no guarantee of a flawless design or perfectly compiling program later on.

Quantitative results

The student average score on the mock TOEIC reading test was 69% at the beginning and 72% at the end. Clearly, this was not a large improvement. The average scores over a semester for other courses of English taught by the same instructor reveal an average 10 points higher, though the range of improvement remains about 5%. Other instructors reported similar results on the same test. Students from the English for Makers cohort who took the formal TOEIC test at the end of the semester scored on par with students who had finished their English in traditional classrooms. While the group held their own on the TOEIC scores, students had difficulty producing written instructions, though their videos generally had a higher degree of polish and accuracy. As writing was not a focal point of the course, and oral communication was effectively the class mode, this outcome is not surprising. Students had difficulty working with the Adobe software even though they had received training from a competent professional. It was later determined that some of the required deliverables may have been excessively difficult or too time consuming to produce. Other issues that came to the fore were that the projects took a great deal of the student's time. Now while this may seem like a legitimate concern, students took a longer time to complete the projects that were challenging than they normally might have with anything in a standard English class. There was also a much longer exposure to English than in a standard course, though because of the number of issues encountered using *Instructables,* it was not always a pleasant experience for the students.

Qualitative results

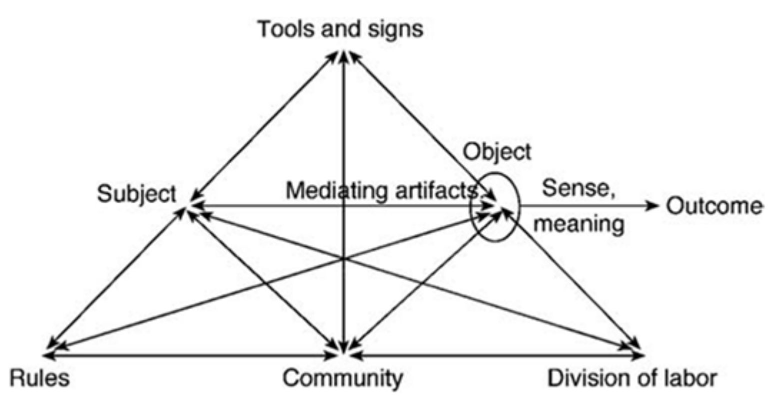
Students were extremely engaged. Friday evening classes in English at this university aren't common. In the eighteen-week run of this course, students continued to voluntarily work on their projects past the class hours on several occasions, while none asked to leave early during the semester. One student achieved a 640 score on her institutional TOEFL. She attributed her high score to the English exposure she got while in the class. Another participant passed a difficult course in circuitry with the highest notes. He attributed his success to having previously learned what he needed to know in the maker course. Additionally, students in the maker course who took the official TOEIC test achieved scores that allowed them to finish the English requirements of their career field, much like those who completed their English in standard traditional courses. So it begs the question: How could students who essentially received no traditional English language instruction still maintain their level of English and in some cases excel in their use of the language?

Discussion

One means of analyzing the efficacy of the learning environment is through activity theory. Activity theory focuses on in the individual's learning as part of a larger social, cultural historical context. The academic discussion of activity theory (AT) traces the roots of AT back to Vygotsky's sociocultural theory. Leontiev, a contemporary of Vygotsky, expanded on the original theory to include collective activities (Haught, 2006). The result of all this is that "activity and cognition are inseparable and unified" (Haught, 2006, p. 2). Of course, where all this becomes most interesting is when the cognition/activity is used to achieve goals. There are several elements to activity theory that may be best understood against the backdrop of the makers class. In his 1987 work, Yrjö Engeström developed a diagram which is reproduced in Figure 1 explaining the activity system.

Figure 1. The structure of a human activity system (Engeström. 2001, p. 135).

Jonassen and Rohrer-Murphy (YEAR) used a similar model as a means of analyzing a CLE and the definitions



they apply to this diagram are as follows:

<u>The subject:</u> This would include the participants in the activity. In the case of the maker course it was the students, the assistants and the professor.

<u>The object:</u> The reason for activity, though it might be better understood as the objective. In the case of the maker course there were several objectives. Officially, the objective was to learn English. For students however, the objective was to make a working object, and explore the making philosophy. English language acquisition was not the highest priority.

<u>Tools and signs:</u> These include all the physical objects such as Arduinos, hand tools, etc. textbooks, and anything that could have an effect on the direction of the activity.

Rules: The basic requirements of the activity, and in the case of this activity, with the exception of deadlines, students were given very few rules to follow. Of those rules, even fewer could be considered traditional class rules of punctuality or even location.

Community: This includes those who might have a peripheral effect on the activity and participants. This would include outside engineering, computer-programming specialists, other makers, interested observers, and in the case of our maker course, visiting faculty and students who were invited to (and often did) participate.

Division of labor: It would include those specialized roles performed by the participants, i.e. student, guide, assistant, the knowledgeable helper. These roles became more fluid as problems arose. Students who had previously solved a similar issue would become the knowledgeable helper and guide the students toward a resolution.

Mediating artifacts: These are defined as both real rules and theoretical ideas that are used to "support and guide decision making, ranging from rich contextually located examples of good practice (case studies, guidelines, etc.) to more abstract forms of representation which distil out the 'essences' of good practice (models or patterns) (Conole, 2009, p. 5). Examples were the tenets of the maker movement mentioned earlier (Jonassen & Rohrer- Murphy, 1999).

In the case of the maker course as CLE, the activity system reveals that a complex system functioned reasonably well with a high degree of interconnectivity between the various, necessary parts of the activity. In order for everything to work well, the subject needs to consciously interact in the activity environment. "Rather than learning before acting as traditional theories prescribe, activity theory believes *a priori* that the human mind emerges and exists as a special component of the interactions with the environment, so activity (sensory, mental and physical) is a precursor to learning (Jonassen & Rohrer- Murphy, 1999, p. 64).

Indeed, activity requires the subject's conscious interaction so that the object, the desired learning, can take place. Conscious interaction is critical, but how were students able to maintain and/or improve their level of English, especially if one of the goals of the activity was not to explicitly teach English?

Because the activity was based in English, as were the problems, and (many times) their solutions, students were compelled to rely on the help of their assistants or the teachers for scaffolded help. The zone of proximal development in this case was extremely narrow. This is also known as asymmetrical scaffolding, in which more knowledgeable peers and teachers impart their knowledge. However, the knowledgeable peers' ability to scaffold was impaired early on, and subjects were compelled to use symmetrical scaffolding, or increase their zone of proximal development. "Learning also occurs between students who have similar levels of conceptual understanding. That is, learning and development may also result from 'symmetrical' interactions (Fernández, Wegerif, Mercer & Drummond, 2001, p. 40). The symmetrical interaction was possible because teaching and learning in a foreign language classroom often times relies on collaboration and a lack of formal instruction, thus allowing for autonomous discoveries about language use (Donato, 2000). Because student autonomy was a necessary component of the makers class, students brought to bear their own learning experiences, technical expertise as well as their own interpersonal skill set. As Donato points out, in classrooms based on sociocultural theory (this would include those classrooms with constructivist learning environments and activity), "agency matters" (Donato, 2000, p. 46). Donato, referring to the sociocultural theory-based class (of which activity theory is a subset), indicates that the collaboration involved between students and between students and teachers creates opportunities that afford many different zones of proximal development. In short, the collaborative nature of these courses allowed for collaborative negotiation of meaning allowing for a deeper learning experience than a traditional classroom (Donato, 2000). The structure of the maker course allowed for students to negotiate meaning and mediate their own learning. Admittedly, they would have to take charge of their own learning since their teacher did not actively seek to teach them any grammar or structure. Where they did confront the language was in their interaction with the learning materials and their student assistants.

Looking again at the activity system map, one might correctly conclude that the learning material and the student assistants formed parts of the tools and signs, as well as mediating artifacts, and as part of the community and the division of labor, respectively. An aspect of the CLE that may seem obvious to discuss but wasn't mentioned in much of the literature about sociocultural theory or activity theory is the situation of learning, or where and in what condition learning took place. In this place, this community, students (future engineers) participate peripherally in the tasks at hand. Essentially, the students learn the ropes of the business, as they might in an apprenticeship or an internship. Jean Lave and Etienne Wenger (1991) refer to this as "Legitimate Peripheral Participation" (LPP). As with the previous constructivist theories that have been mentioned, LPP "provides a way to speak about the relations between newcomers and oldtimers, and about activities, identities, artifacts, and communities of knowledge and practice. It concerns the process by which newcomers become part of the community of practice" (Lave & Wenger, 1991, p. 29). The community of practice in the case of the makers course required those who did not know how circuitry and fabrication worked to become part of the class community, which just happened to be in an English-speaking context. The two assistant students were indispensable in their role as 'oldtimers', and again referring to the activity map, these 'oldtimers' were mediating influences on the learning. They were instrumental in maintaining the 'situatedness' of the learning both in terms of technical expertise, and the linguistic context of the activity system. Finally, while the structure of the class did perform well as an activity system, and all the pieces for self-mediation and symmetrical scaffolding were in place and there were abundant zones of proximal development in place for students to take advantage of, one might be left to wonder what motivated the students to continue learning, even when they were faced with the dual frustrations of difficult to follow or missing programming and dealing with that issue in a second language? What kept these students engaged to the point of skipping break times and staying late after class to finish their work? The answer lies in experiential learning.

According to David A. Kolb (1984) in *Experiential Learning: Experience as the Source of Learning and Development,* Experiential learning theory can be traced back to Lewin, Dewey, and Piaget, and their work resulted in the theory that experiences that occur to a learner inform their learning. The learning is made possible by meaningful review of the experience that informs the next action which leads to the next experience, (Kolb, 1984). Kolb states that learning is a process full of tension and conflict:

> *New knowledge, skills or attitudes are achieved through confrontation among four modes of experiential learning. Learners, if they are to be effective, need four different kinds of abilities--concrete experience abilities (CE), reflective observation abilities (RO), abstract conceptualization abilities (AC), and active experimentation abilities (AE). That is they must be able to involve themselves fully, openly and without bias in new experiences (CE) they must be able to reflect on and observe their experiences from many perspectives (RO). They must be able to create concepts that integrate their observations into logically sound theories (AC) and they must be able to use these theories to make decisions and solve problems (AE).* (Kolb, 1984, p. 30)

Conclusion

To conclude, Kolb adds that learners must go from a concrete experience to theorizing about possible solutions to problems, and it's in this push and pull that experiential learning takes place. The experience, at least in the terms of the makers course was student-driven in that students chose their own projects to do. The richness of the experience became noticeable as problems arose. Kolb offered a particularly apt quote from Hegel that summarizes exactly what a learning experience should be: "It's in the interplay between expectation and experience that learning occurs. In Hegel's phrase, 'Any experience that does not violate expectation is not worthy of the name experience'" (Kolb, 1984, p. 28). It's at this juncture, between expectation and experience where the activity system of the makers course could function efficiently and allow for an uninterrupted flow of learning unobtrusively in the second language.

Students brought their previous experiences in second language use, and these experiences were immediately and personally put to use in a second language use context. The challenge then becomes twofold when one considers the student's previous knowledge or lack thereof. The motivation here is provided by their exposure to a problem, participation in collaboration to solve a problem, internalizing of information and corrective action, as well as disseminating their knowledge (Knutson, 2003). In the second language classroom, rapid feedback in problem solving both increases learning and confidence in the use of the target language. In the case of the makers course, students helping each other using their own experience in language use and their technical expertise were much more rapid in how they corrected errors in use or meaning than in a traditional language class.

Far from a traditional class, the English for Makers experience proved successful on several fronts. It allowed students to explore a new topic in a novel way through the use of new tools, new methods, and all in a second language learning context.

In general, the course performed beyond expectations, but it remains to be seen if the course could be used in an independent setting where there may be limited resources and with learners who might have extensive gaps in their language learning or who might not have competent, capable instructors. The next iteration of the course will include more components such as the use of a Moodle LMS and student designed feedback systems to enhance the autonomy of the course for teachers, students, and limited-resource communities. Additionally, the next course iteration will include less costly learning objects and projects that will accomplish some of the same objectives that were achieved in the maker course. Finally, in order to meet expectations of the more traditional teaching-oriented professionals, a language guide will be developed to reflect vocabulary, technical English, specific idiomatic expressions and collocations, though given the theoretical data and the information gathered in this experiment, the guide will be more likely useful to the teacher rather than the student.

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