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Learning Tools for STEM Students: A focused exploratory project with broad potential

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I have been a math teacher for 35 years. Last 27 years, I am an Associate Math Professor at National Technical Institute for the Deaf at Rochester Institute of Technology. I had been doing research projects involving Problem Solving, Fractions and effective tutoring as well as teaching for the deaf students.

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Background

By law, educational institutions must provide reasonable and appropriate accommodations to ensure equal access to education for students with disabilities. For Deaf and Hard of Hearing (DHH) students this is generally considered to consist of *communication access* – that is, audio, text and/or sign language accommodations that allow DHH students to receive information contained in spoken language. But access to communication does not necessarily ensure *access to information*, which we define as use of multiple communication modes and/or multiple representations of concepts to present information so that individuals understand the content of the message. Teachers of introductory technical courses such as statistics face multiple challenges in the classroom, including low motivation and insufficient mathematical backgrounds of students (Onwuegbuzie, 1997), as well as obstacles in communication related to the dependence of interpretations on language (Rangecroft, 2002).

DHH students have struggled with both reading and math for decades, with limited progress. In 1996 the Gallaudet Research Institute reported that deaf 18 year-olds' median grade level for reading was 3.9, a result that has persisted over time. While scores are generally higher in math than reading the gap in both is still too wide. Qi and Mitchell reviewed the standardized test scores over three decades for DHH students. While they critiqued the process and accommodations for testing this sub-population they acknowledge that the "performance of deaf and hard of hearing students has been consistently below hearing students" (Qi and Mitchell, 2012, p. 7). Further, they note that with the possible exception of mathematics problem solving between 1983 and 1990, the achievement gaps have not significantly improved over the three decades reviewed.

Research has identified specific areas of challenge and examined possible strategies to increase the success of DHH students in math. In some cases, the combination of low reading comprehension and mathematical computation compounds DHH students' difficulties. For example, Kelly, Lang, Mousley and Davis (2003) confirmed that DHH college students are more likely to make a mistake when the relational statement of a word problem is inconsistent with the mathematics operation to be performed – a theory initially proposed as the consistency hypothesis (Lewis and Mayer, 1987). In another study, Mousley and Kelly (1998) studied the impact of several strategies to enhance student success with word problems in college-level mathematics. They found that students were more successful if they visualized the problems or the instructor demonstrated the problem before they tackled it themselves. Kelly and Mousley (2001) conclude from their study of DHH students' performance in solving word problems that the barriers are not limited to reading level: additional causes proposed include student disengagement when presented with word problems, a lack of focus on the problems, and difficulties with problems that require reference to two or more events, all of which may be improved with additional instruction and practice.

Educational researchers have also explored the potential for mediated instruction in mathematics for students of all ages, in which the traditional learning format is supplemented in some fashion by alternative methods of learning. Some of these interventions have utilized generalized approaches while others have focused on one or just a few strategies. One general approach is to incorporate visual and kinesthetic strategies into math instruction. For example, Chen (2005) discusses the use of origami as a visual and tactile vehicle to explain math concepts to students. Another approach incorporated general strategies to create a hybrid intervention. In this vein, Kritzer and Pagliaro (2013) used a hybrid in-person and online format to facilitate parent-child interactions that increase their DHH preschooler's awareness and knowledge of foundational math concepts through daily activities. At the postsecondary level, Kelly (2003) reports on Project Solve, (http://www.rit.edu/ntid/rtes/probsolv/), a more focused approach which provides DHH high school and postsecondary students with "web based problem-solving instruction and guided practice for mathematical word problems (p.8)." This tool allows students to work through a range of arithmetic and algebra word problem categories at their own pace, reviewing materials as needed, responding to prompts for submitting answers, and requesting help.

The Thinking CAP Project

Statistics is central to research in most STEM disciplines. Thus, introductory statistics is a gateway course in the development of students into research scientists. Deaf and Hard of Hearing (DHH) learners often receive less attention from mainstream instructors who believe that, with sign language interpreters and other support services, DHH students have equal access to learning in their classrooms. Yet access often falls short of "equal" due to variations of instructional skill, interpreter knowledge of the discipline, and the lack of alternative representations of content. DHH learners have historically received less attention from researchers due to a perception that results would benefit only this small group. As a result, improvements in access, success and retention in STEM majors for this population continue to be a concern. Project Thinking CAP: Communication, Access, & Persistence Among Deaf And Hard of Hearing Students in Foundational Statistics Courses is investigating the potential of Supplemental Online Learning Tools (SOLTs) to enhance the academic success of DHH students in foundational statistics courses. SOLTs integrate visual and textual representations of concepts with explanations in sign language, voice and captioning.

This project utilizes a partnership among three colleges of Rochester Institute of Technology – the College of Science, the National Technical Institute for the Deaf, and the Golisano College of Computing and Information Sciences. The diverse team of hearing and DHH members includes instructors in statistics/math, game design instructors with a specialization in educational games, tutors, students, visual learning specialists and American Sign Language (ASL) interpreters. Core objectives include **1)** develop a pilot collection of SOLTs and **2)** test the efficacy of these videos. Along the way, a third objective has emerged: Embed the SOLTs into an interactive web-based experience in which students can obtain, describe, and make inferences from samples within a relevant and appropriate context.

In the first year of this exploratory project, statistical concepts were selected using multiple data sources and encompass concepts that are built upon throughout the introductory statistics course. The selection process that was developed incorporated the following:

- **Criteria**: Topic selection for the first SOLT used two main criteria – scope of student impact and the degree to which the concept is foundational.
- **Measures:** We identified measureable quantities for each criterion.
- **Data Sources**: Sources of data were specified for each measureable quantity.

Table 1 shows guidelines and data supporting the selection of the topic for the first SOLT, "Identifying Data Type". This includes determination of population versus sample as well as categorical versus numerical. Identifying data type is critical in the selection of appropriate statistical techniques for a data set.

The design of each SOLT incorporates a series of micro-videos that breaks a topic into parts, and explains the terms and concepts needed to understand the topic. We created two pilot videos for the first micro-video on "Population and Sample". One video was created in Microsoft Powerpoint, with voice of the instructor and video of ASL interpretation, similar to how DHH students in mainstream classes receive instruction. The other video recorded a deaf teacher using the same Powerpoint presentation but providing "direct instruction" in ASL. At this point, we conducted focus groups with DHH students to obtain feedback on accessibility of the two pilot videos. Analysis of the transcripts from these sessions revealed five themes:

1. Student honesty about technical and design issues focused on pace, captioning, interpreting
2. Students' positive feelings about being asked to provide feedback
3. The "virtually impossible" task of attending to multiple visual information sources simultaneously
4. Students' preferences for different kinds of presentation, leading to the question "should options - captioning, color, etc. - be customized?"
5. Students' general preference for the direct instruction video

During the discussion, students also offered their thoughts about engagement. This quote from one student aptly describes the consensus, "[This] could be more interesting and more fun and engaging… You could do different game [with] questions [and get] more creative."

During the second year, the team developed practices for creating videos to enhance accessibility for DHH students, produced additional videos, and designed an educational gaming framework to link the videos to applications and engage students. We filmed direct-instruction ASL videos with a "green screen" making visuals larger and easier for the deaf instructor to reference. The instructor-interpreter/Powerpoint videos were adapted to allow students to control the pace by clicking when they are ready to move on, even clicking through the interpreter if not wanted.

Eventually, we decided to create only direct instruction videos. Of course, a benefit of this decision is that it reduced the scale of work that had doubled with making two versions of the video for each concept. More importantly, however, this is a significant symbolic gesture for DHH students. Most of the time DHH students use tools created for hearing students, accessible to them through accommodations. The videos we are creating are specifically for ASL users, accessible to hearing students through accommodations.

Table 1. Guidelines and Data Supporting Choice of First SOLT Topic

Criteria	Measures	Data Sources	TOPIC = Identifying Data Type
Scope of student impact	Fall 2014 students in one section: % DHH students who struggle (primary), % all (DHH and hearing) students who struggle (secondary)	Student Performance - In-Class Exams (#1, #2, #3) Fall 2014 - Final Exam Fall 2013 - Common Errors on Exams (myCourses postings) by one instructor over ten terms	High % DHH students struggled Exam #1 - representing numerical data in histogram Exam #1 - sample standard deviation vs. population standard deviation Exam #3 - correct formula depends on knowing data numerical or categorical Exam #3 - interpretation in context depends on numerical vs categorical AND sample vs population Final Exam - how to create and use cheat sheet depends on identifying population/sample and numerical / categorical
	Degree and type of difficulty that topic has for DHH students	Student Feedback - Pre/post-class feedback cards for students in two sections of the course - Reflection and discussion of student research team members (who have already completed the course)	Student feedback after class: Regarding sample size determination, a hearing student's comment on what is confusing: "When to use which formula" – this depends entirely on determining the type of data; after class this day, 33% of hearing students in the class and 0% of DHH students felt they had high level of knowledge about this material. After review and reflection of the material across the entire course, student team members identified data/variable types as one of their top five difficult concepts.
Degree to which the concept is foundational	# of later topics in the first course that build on this	Foundational Measures - # class meetings for this course in which the concept is used - Where concept occurs in Peck, Olsen Devore text's order of topics	84% of class days build on identifying data type
	Place in order of topics specified by statistics education experts		Identifying data type occurs in module #1 (out of 10)

An additional core objective emerging for this project is to embed our Supplemental Online Learning Tools (SOLTs) into an interactive web-based experience (in a game format) in which students can obtain, describe, and make inferences from samples within a relevant and appropriate context.

An Interactive Experience

Our target population of DHH students tends to lag behind in English and math and often require visual presentation of concepts, making them an ideal audience for an interactive educational experience. Why? Because video games are very visual and have been shown to increase learning and motivation.

Dondlinger's (2007) review of educational video game research refers to the use of situated cognition as a meaningful framework for the study of games (Halverson, Shaffer, Squire, & Steinkuehler, 2006), "given that games have an ability to situate learning in an authentic context and engage players in a community of practice" (p. 26). In comparing students who played the simulation-game Supercharged! to a control group learning through guided discovery methods, Squire, Barnett, Grant and Higginbotham (2004) found that the game players had better mastery of abstract and conceptual knowledge related to electromagnetism and attributed this phenomenon to the simulation game's capacity for replay. In essence, "playing" with the material allowed for trial-and-error feedback and resulted in increased learning. Dondlinger (2007) also states that "Other studies concurred with the findings of Squire, Barnett, Grant, and Higginbotham (2004) concerning mastery of abstract and conceptual knowledge through game play (Aguilera & Mendiz, 2003; Gee, 2003; Lunce, 2006; Prensky, 2006)," p. 26.

Student engagement can also be enhanced with video games. Annetta, Minogue, Holmes, & Cheng (2009) conducted a quasi-experimental study with high school students taking general biology that evaluated the affective and cognitive impact of a video game about genetics. While student learning was not impacted by use of the video game, the participants' level of engagement while interfacing with the video game increased. In a study of high school students' knowledge of computer memory concepts, Papastergiou (2009) showed that a gaming approach was more effective and more motivational than the non-gaming approach.

Students with academic challenges may gain the most from increased engagement. Klopfer and Yoon (2005) conducted a qualitative study of StarLogo, a simulation environment in which students build models that convey authenticity in scientific investigations, and discovered that struggling students better understood complex systems after working with StarLogo. More generally, Carini, Kuh, and Klein (2006) examined individual student data from fourteen four-year colleges and universities looking for possible links between self-reported student engagement and scores on cognitive and performance tests. Measures of student engagement had positive, albeit mostly weak, relationships with learning outcomes. Further, results suggest that the lowest-ability students had a greater benefit from engagement.

Next Steps

The third year of the project (the current year) is focused on development of a working prototype for the interactive experience, creating further SOLT videos, and testing the efficacy of these tools. SOLTs will serve as stand-alone tools and tutorials within the interactive experience. This web-based tool will be mobile compatible and incorporate visuals that align with those in the SOLTs.

The framework for the interactive experience will eventually encompass multiple scenarios in which to play. We are currently working with one scenario – a student government election at the fictional Mars University. Within this environment, students select a candidate for whom they will campaign, take polls to guage the student body's preferences, and perform activities that attempt to sway opinions. The interactive experience entered production in Summer of 2016 and is currently in the alpha phase. SOLTs will serve as stand-alone tools and tutorials within the interactive experience. Students may start by watching one or more SOLTs or jump straight into the interactive experience and use the SOLTs as supports when needed.

This project has the potential to increase learning for DHH students in statistics, increase the number of DHH students who continue to pursue statistics or other STEM disciplines, and contribute to diversity within STEM workforce careers. Other learners may also benefit from visual representation of complex concepts. It is estimated that ≈65% of the population are visual learners, as are half of all students in special education programs. The potential for the broader application of SOLTs and interactive experiences in other STEM subjects for DHH or other students may increase knowledge of how diverse groups of visual learners access complex concepts.

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References

Aguilera, M. D., & Mendiz, A. (2003). Video games and education: (education in the face of a "parallel school"). *ACM Computers in Entertainment*, *1*(1), 1. http://dx.doi.org/10.1145/950566.950583

Annetta, L. A., Minogue, J., Holmes, S. Y., & Cheng, M. T. (2009). Investigating the impact of video games on high school students' engagement and learning about genetics. *Computers & Education*, *53*(1), 74-85. DOI: http://dx.doi.org/10.1016/j.compedu.2008.12.020

Carini, R. M., Kuh, G. D., & Klein, S. P. (2006). Student engagement and student learning: Testing the linkages. *Research in Higher Education*, *47*(1), 1-32. http://dx.doi.org/10.1007/s11162-005-8150-9

Chen, K. (2006). Math in motion: Origami math for students who are deaf and hard of hearing. *Journal of deaf studies and deaf education*, *11*(2), 262-266. https://doi.org/10.1093/deafed/enj019

Dondlinger, M. J. (2007). Educational video game design: A review of the literature. *Journal of Applied Educational Technology*, 4(1), 21-31. Retrieved from https://pdfs.semanticscholar.org/2138/314c9bad5cd9aa5583a55a3b3eb7baaf2aaf.pdf

Gallaudet Research Institute (1996). *Stanford Achievement Test 9th Edition*. Washington, D.C.: Gallaudet University.

Gee, J. P. (2003). *What video games have to teach us about learning and literacy*. New York: Palgrave MacMillan. http://dx.doi.org/10.1145/950566.950595

Halverson, R., Shaffer, D., Squire, K., & Steinkuehler, C. (2006). Theorizing games in/and education. In *Proceedings of the 7th international conference on Learning sciences* (pp. 1048-1052). International Society of the Learning Sciences.

Kelly, R. R. (2003). Using technology to meet the developmental needs of deaf students to improve their mathematical word problem solving skills. *Mathematics and Computer Education*, *37*(1), 8-15. Retrieved from http://cimm.ucr.ac.cr/ojs/index.php/eudoxus/article/view/302/274

Kelly, R. R., Lang, H. G., Mousley, K., & Davis, S. (2003). Deaf college students' comprension of relational language in arithmetic compare problems. *Journal of Deaf Studies and Deaf Education*, *8*(2), 120-132. https://doi.org/10.1093/deafed/eng006

Kelly, R. R., & Mousley, K. (2001). Solving word problems: More than reading issues for deaf students. *American Annals of the Deaf*, *146*(3), 251-262. http://dx.doi.org/10.1353/aad.2012.0088

Klopfer, E., & Yoon, S. (2005). Developing games and simulations for today and tomorrow's tech savvy youth. *Tech Trends*, *49*(3), 33-41. http://dx.doi.org/10.1007/BF02763645

Kritzer, K. L., & Pagliaro, C. M. (2013). An Intervention for Early Mathematical Success: Outcomes from the Hybrid Version of the Building Math Readiness Parents as Partners (MRPP) Project. *Journal of deaf studies and deaf education*, *18*(1), 30-46. https://doi.org/10.1093/deafed/ens033

Lewis, A. B., & Mayer, R. E. (1987). Students' miscomprehension of relational statements in arithmetic word problems. *Journal of educational psychology*,*79*(4), 363.

Lunce, L. (2006). Simulations: Bringing the benefits of situated learning to the traditional classroom. *Journal of Applied Educational Technology*, *3*(1), 37-45. Retrieved from http://www.eduquery.com/jaet/JAET3-1_Lunce.pdf

Mousley, K., & Kelly, R. R. (1998). Problem-solving strategies for teaching mathematics to deaf students. *American Annals of the deaf*, *143*(4), 325-336. http://dx.doi.org/10.1353/aad.2012.0082

Onwuegbuzie, A. J. (1997). Writing a research proposal: The role of library anxiety, statistics anxiety, and composition anxiety. *Library and Information Science Research*, *19*(1), 5-33. http://dx.doi.org/10.1016/S0740-8188(97)90003-7

Papastergiou, M. (2009). Digital game-based learning in high school computer science education: Impact on educational effectiveness and student motivation. *Computers & Education*, *52*(1), 1-12. http://dx.doi.org/10.1016/j.compedu.2008.06.004

Prensky, M. (2006). *Don't bother me mom--I'm learning*. St. Paul, MN: Paragon House.

Qi, S., & Mitchell, R. E. (2012). Large-scale academic achievement testing of deaf and hard-of-hearing students: Past, present, and future. *Journal of Deaf Studies and Deaf Education*, *17*(1), 1-18. https://doi.org/10.1093/deafed/enr028

Rangecroft, M. (2002). The language of statistics. *Teaching Statistics, An International Journal for Teachers*, *24*(2), 34-37. http://dx.doi.org/10.1111/1467-9639.00080

Squire, K., Barnett, M., Grant, J. M., & Higginbotham, T. (2004). Electromagnetism supercharged!: Learning physics with digital simulation games. In *Proceedings of the 6th international conference on Learning sciences*, (pp. 513-520). International Society of the Learning Sciences.