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Improving oral presentations: Inserting subtitles in videos for targeted feedback[1]

Hanna Yang[2] and Lauren F.V. Scharff[3]

Abstract: Instructors are increasingly using videotaping in addition to written summarized feedback to develop oral presentation skills, but reviewing videotapes with students can be a time-consuming process. Moreover, students may find that summarized feedback, which is displaced from the video itself, is vague and unhelpful. This project investigated a new way for instructors to deliver targeted feedback within video recordings, and embedded the new approach within other best practices (e.g. rubrics, guided self-reflection). We compared two groups (N=31) across two presentations, with one group first receiving videotapes that included interjected feedback, much like subtitles, in their videos, while the other group first received raw videotapes and met face-to-face with their instructor to review their performance. Despite the significant student perception that face-to-face feedback was more useful, our results showed that interjected feedback was more helpful for developing students' style skills, and there was no difference in improvement across presentations for content, organization and response to audience. Across both groups, students reported great benefit of video feedback because it provided them with a third-party perspective of their own performance. Furthermore, interjected feedback provided instructors with a substantial time savings compared to the face-to-face meetings.

Keywords: oral presentations, feedback, videotaping, best practices

Providing meaningful feedback to students amidst the challenges of balancing the timeliness of the feedback with the quality of the feedback is a familiar struggle for most educators. This balance is particularly difficult to strike in the context of helping students improve their oral communication skills due to the ephemeral nature of the presentation. To address these challenges, some educators have turned to technology, for example videotaping student presentations. One relatively common way that instructors use video feedback to promote student development is to schedule meetings with students to replay the videotapes and analyze the students' performance together. Unfortunately this can pose an unsustainable burden of time and coordination for both parties, especially the faculty member. Further, technology alone does not provide a complete solution (Amirault & Visser, 2009); it should be embedded within a course design that aids and incentivizes the students to conduct meaningful self-analysis and promote the development of targeted skills. While the few published studies available regarding the use of videotaping oral presentations share positive views of the practice, none share data on the development of oral presentation skills, nor do they address how the use of videotaping fits within a course design that embeds other, known best practices. Thus, the purpose of this project

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[2] Hanna Yang, Department of Law, U.S. Air Force Academy, 2354 Fairchild Drive, Suite 4K25, U.S. Air Force Academy, CO 80840 hanna.yang@us.af.mil

[3] Lauren F.V. Scharff, Director, Scholarship of Teaching and Learning, U.S. Air Force Academy, 2354 Fairchild Drive, Suite 4K25, U.S. Air Force Academy, CO 80840, lauren.scharff@usafa.edu

was to find and assess a way to help instructors provide timely, meaningful, and sustainable feedback to students about their oral communication skills that was also likely to be used by students.

Literature Review

Feedback is a crucial aspect of the learning and development process because it helps target specific deficiencies and strengths, and provides formative guidance for development (for a nice overview of evidence, see Chang et al., 2012). However, most instructors will readily admit that the process of grading and providing meaningful feedback is one of the least desirable aspects of their work. Further, although some students are increasingly demanding more feedback from their instructors (Chang et al., 2012), a large number of students also exhibit behaviors that indicate they do not value feedback, (e.g. failing to collect feedback, quickly glancing at their grades rather than taking time to read the feedback comments). To further complicate the "messages" received by faculty, some students indicate they prefer quality feedback over timeliness, whereas some indicate that they value timeliness over quality feedback (Chang et al., 2012; Winter & Dye, 2004). It was within this mixed context that we approached our goal of oral presentation skill development, using technology as a tool embedded within other best practices.

Oral Presentations—Feedback Challenges and a New Approach. Oral presentations pose several challenges for instructors with respect to their ability to provide meaningful, formative feedback. First, in contrast to written papers, oral presentations operate on a real-time basis, so without video capture, they leave no tangible artifact that students and instructors can review and assess. Second, students may perceive a lack of clarity, reliability, validity, and fairness in the criteria used for assessing oral presentation skills (e.g. Cooper, 2005; Price, Handley, Millar, & O'Donovan, 2010). For example, oral presentation assessments often emphasize content more than command of the oral medium, or command of the oral medium more than content, leading to an imbalanced assessment of oral presentation skills (Cooper, 2005). The uneven focus is likely due to the fact that, without a videotape to allow multiple viewings, it is difficult to pay detailed attention to both aspects (content and style) of the presentation. A third challenge is that the nature of oral presentations does not naturally lend itself to the type of accurate, targeted commenting that instructors often provide in specific parts or margins of papers (McKeachie & Svinicki, 2006), which provides students with subsequent opportunities for guided self-reflection. Studies have shown that feedback needs to be specific to be effective (e.g. Gibbs & Simpson, 2004), but students often feel that instructor feedback is vague, difficult to follow, and not useful (Price et al., 2010). With only summarized feedback provided separately from the oral presentation, it is easy to understand how the perception of vague and confusing feedback could be perpetuated in the context of oral presentation feedback. Finally, a fourth challenge is the issue of timeliness of the feedback. Studies have shown that if students do not receive timely feedback, they will be likely to disregard the feedback they eventually receive, based on the perception that such feedback is now irrelevant (e.g. Gibbs & Simpson, 2004; Winter & Dye, 2004). Our personal experience suggests that the process takes several days, or in some cases, weeks to provide feedback for an entire class. These observations align with those of Kovach (1996) who reported that efforts to capture oral presentations on video and provide instructor feedback require a formidable amount of time, administration, and cost.

The above workload issues might suggest that the drawbacks of videotaping oral presentations overcome the benefits. However, video capture has increasingly been used in many disciplines to provide feedback for improving oral communication skills, for example in medicine (Savoldelli, Naik, Park, Joo, & Hamstra, 2006; Byrne, Sellen, Jones, Aitkenhead, Hussain, Gilder, Smith, & Ribes, 2002) and law (Kovach, 1996; Legal Research and Writing Listserv responses, 2011). However, as we considered our own incorporation of videotaping student oral presentations, we realized that even the above-published "successes" had shortcomings. Simply providing students with videotapes does not provide students the targeted guidance and feedback they need to meaningfully reflect on their videos (Cooper, 2005). Further, although face-to-face feedback enables targeted commenting during the meeting between the instructor and the student, it does not provide a historical artifact of targeted comments for students to review on their own. What if we could give targeted feedback in a manner that also allows students to have a permanent record of their presentation, i.e. interjected video feedback?

Our new approach, interjected video feedback, is textual instructor feedback that is manually inserted into a video at specific timeframes of a student's performance, much like subtitles, thereby enabling a student to replay the video and see which specific moments in his or her presentation that did or did not meet the assessment criteria, as well as the manner by which they did or did not meet the assessment criteria. This is akin to comments interjected in a student's written paper, which allows instructors to pinpoint specific writing issues at the precise points at which they occur, rather than in a global summary at the end of the student's paper. Moreover, interjected video feedback can be replayed by students at their leisure, providing them with multiple opportunities to review and self-assess their oral presentation skills.

We also acknowledge that technology, in and of itself, rarely provides a complete solution. Therefore, we incorporated as many best practices about feedback into this project as possible in order to place our use of interjected videotaped feedback in a context that both supported student learning and skill development, and maintained a manageable instructor workload.

A Framework of Best Practices. The major challenges we hoped to address with our course design and new technique were those of clarity and reliability of assessment, of student use of feedback, and of time and workload. No one best practice addresses all of these challenges, so we incorporated multiple practices: the use of a developmentally-oriented rubric combined with summarized feedback, student assignments requiring review of their videotapes and response to guided self-reflection questions, and more than one oral presentation assignment so that skills could develop. In order to test the impact of the new, targeted, interjected feedback, we randomly assigned half the students to receive it for the first presentation, while the other half received it for the second presentation.

Rubrics have been shown to be a helpful tool for providing timely, yet detailed feedback, as well as explicitly conveying the instructor's expectations to students (Stevens & Levi, 2005; Andrade, 1997). Our rubric was also "developmental" in tone, in order to emphasize the process of learning. Whereas some rubrics evaluate students' demonstration of assignment components, (e.g. "Style" or "Content") using end-state terms, such as "Poor," "Good," or "Excellent," our rubric evaluated students using terms denoting progression, namely by using the following terms: "Not Acceptable," "Beginning," "Intermediate," and "Advanced." Further, along with the rubric performance-level indications, we included several sentences of summarized comments at the end of the rubric feedback form. Such summarized feedback provides more context, explanation, and in-depth insight about the student's performance, and it can help students understand the connection between their performance and scores on a standardized rubric. Without the benefit of a rubric, summarized feedback may be perceived as unstructured, and therefore, unclear.

Our self-guided student reflections also encouraged students to make links between the rubric dimensions, i.e. instructor expectations, and their performance. As noted above, many students do not deeply process feedback, and thus, they do not use that feedback to shape their future efforts. By building guided self-reflection assignments into the course, we "forced" students to review their performance (watch their own video), identify specific behaviors that linked to each rubric component, and generate steps to improve each component in subsequent presentations. This guided reflection design follows from Nicol and Macfarlane-Dick's (2006) conclusion that students can only learn from their self-reflection if their reflection is informed by, or measurable against, specific goals, criteria, or standards.

The third best practice we incorporated, multiple opportunities for development, supports long-time understanding of the role of practice in skill acquisition (e.g. Newell & Rosenbloom, 1980), as well as further promotes student use of feedback. By requiring students to come up with the self-reflected steps for improvement, we more explicitly framed the oral presentations as part of a developmental process, which framed the instructor's feedback from the first presentation as part of a feed-forward process. Studies have shown that students will often dismiss feedback if they believe that the feedback only pertains to a discrete assessment (Gibbs & Simpson, 2004; Price et al., 2010). Thus, this aspect of our design was incorporated to increase the value that students placed on the feedback, increasing the likelihood that they would use it to guide their development, not just because they were required to as part of the self-guided reflection assignment.

Justification for Research. This project was designed to evaluate the impact of interjected video feedback on the development of students' oral presentation skills and on student attitudes about the value of oral presentation feedback. We believed this new type of feedback could provide the specific, targeted guidance that would support student development equally well as face-to-face meetings during which the instructor and student review the video together, which has been the standard way for instructors to share targeted presentation feedback with students. Further, instructor load would be reduced somewhat; a pilot study indicated that it took about half as much time for the instructor to watch a video presentation and interject the comments as to meet face-to-face with a student and share the same points.

However, we acknowledge that there are qualitative differences between the interjected feedback, which is completely instructor determined, and the feedback that can occur during a face-to-face meeting, where students can direct some of the focus and also request elaboration or clarification. This personal tailoring within the face-to-face feedback process might make it more likely that students and instructors reach a common understanding on the assessment goals. On the other hand, our pilot data also indicated that some students may feel uncomfortable meeting face-to-face with instructors about their performance, and prefer to watch themselves in the privacy of their own rooms. Therefore, this study was designed to compare the impact of interjected video feedback with face-to-face feedback, embedded within the best practices described above, on both student performance as well as student attitudes.

Methods

Participants

Participants were 31 students from two sections of a core law course for sophomores at an institution in the Midwest. While students are placed into course sections randomly by the registrar's office each semester, in this case, the section of students receiving the face-to-face feedback first had an average Academic Composite (Accomp) score of 3461.69, while the students receiving interjected feedback first had an average score of 3240.6 (max possible is 4,400, and most of our admitted students have a score of at least 2500).

Research Design

This study incorporated a two-group design with counterbalancing across two oral presentation assignments. One of the two sections was randomly selected to receive interjected video feedback following the first presentation, while the other section first received the raw video plus engaged in a face-to-face meeting with the instructor to review the video (N_{Int}=16, N_{F2F}=15). The opposite types of feedback were given to each section following the second presentation. Both groups for both presentations received summarized written feedback plus rubric scores (see details below), and completed the reflection assignment (see details below).

Dependent variables included performance scores, reflection assignment responses, and subjective feedback collected with an end-of-course questionnaire (see details below). In order to control for possible experimenter bias, a blind grader (not the instructor, and someone who did not know which students had received interjected feedback or face-to-face meeting with the instructor after their first presentation) used a rubric to assess the videotaped performances of the two student groups (the instructor graded the presentations separately for input into the course grade).

Materials

Equipment and software. Currently, there is no software that allows instructors to accomplish video capture and interjected instructor feedback on a real-time basis, which would be most ideal and alleviate the stresses of time, administration, and cost. Thus, we investigated several current software applications that would allow instructors to insert comments post production (e.g. Camtasia, YouSeeU, Screen-cast-o-matic, Windows Live Moviemaker). Additionally, we considered lecture capture systems that simultaneously capture a video and information written within a document shown on a screen, but then the comments are spatially displaced from the video. Based on cost and ease of use, we chose Windows Live Moviemaker 2011. This software application is free and intuitive to use for the interjection of short tailored feedback in the form of subtitles at specific points within the videos. Since we ran our study, a newer version of Moviemaker, Windows Moviemaker 2.6, was released. Compared to the old version, the newer version of Moviemaker requires a few additional steps to interject comments. A handheld camera was used to videotape the oral presentations.

Video scoring key. To streamline the interjected commenting process and to minimize students' distraction level while they viewed their videos, the instructor created and used a video scoring key (see Table 1). So, for example, instead of inserting lengthy phrases, paragraphs, or narrative, the instructor might for example type in "Tr-" to mark that a student transitioned poorly from one subject to the next or "To+" to indicate that a student demonstrated a very appropriate tone while making his or her legal argument. The video scoring key was based on the rubric that students were provided prior to their first and second oral advocacy exercises.

Table 1. *Video Scoring Key for Interjecting Comments in Students' Presentation Videos.*

Key	Skill being assessed
K	Knowledge of subject matter
S	Support (law/facts) for your points
Tr	Transitions
L	Logic of sequence
IP	Information's purpose
W	Word choice
P	Pace
V	Volume
To	Tone
A	Articulation (grammar, enunciation)
I	Inflection (of voice)
EC	Eye contact
M	Movements
R	Responsiveness to audience's questions/ answers
E	Engagement level

Note. The instructor used a "+" or "-" after interjecting a key letter to indicate whether the student's skill was strong or needed improvement.

Rubric. A rubric was created to address the widespread student perception that oral presentations are graded too subjectively and to guide the blind grader's scoring. Each component of the rubric (Content, Organization, Style, and Responds to Audience) and each level of achievement (Not Acceptable, Beginning, Intermediate, and Advanced) was derived from our institution's outcomes for oral communication skills. The specific expectations for each level of achievement were tailored to both the oral advocacy focus of the course and the sophomore level of the students. Each level of achievement had a small range of possible scores, with a maximum of 10 points per component.

Summarized feedback. The summarized feedback included instructor's comments as well as a compilation of in-class peer critiquers' comments. Written comments in the form of full sentences were provided under headings that aligned with the rubric components: Content, Organization, Style, and Responds to Audience.

Guided self-reflection assignment. The guided self-reflection required students to view their videotaped performance (half of them having interjected comments) and list specific instances of both strong and weak performances under each component (Content, Organization, Style, and Responds to Audience). They were required to explain why their performance would have merited a certain level of achievement (Not Acceptable, Beginning, Intermediate, or Advanced), *using the language from the rubric*. Furthermore, students were required to describe specific steps they planned to take to improve in each component. This assignment helped ensure that the students would closely review their videos, because anecdotal feedback from prior semesters indicated that many students avoided watching themselves because it made them uncomfortable. By requiring students to incorporate the language from the rubric, we created a structured framework for students to self-reflect and increased the connection between the instructor's expectations and the students' understanding about the assessment's goals.

Student subjective feedback questionnaires. To ensure a more comprehensive understanding of the role of interjected feedback in developing students' oral communication skills we created an end-of-semester questionnaire that asked students for their perceptions about the usefulness of viewing the videos, of the instructor's written feedback (rubric scores and comments), of the interjected comments in the video, of the self-guided reflection, and of the rubric criteria. Two additional questions asked about the clarity of the rubric criteria, and the number of times students reviewed their videos beyond what was required for the self-reflection.

Procedure

During the course of one semester, students in the course were required to deliver two oral arguments, each lasting 8 minutes. During each presentation, students presented their evaluation and advocacy of a legal problem to fictional justices of the court (role-played by fellow classmates). The handheld camera was placed on a tripod and positioned to capture the speaker at a podium (the speaker stayed at the podium for the entire presentation). Each observing student was given a copy of the peer review form, which they completed as the presentation occurred and then submitted to the instructor.

Following the presentations, the instructor transferred the media files of the students' presentations from the handheld camera to a PC computer, opened up the media files on her computer using Windows Moviemaker, and used the "Caption" function to insert comments using the shorthand letters from the video scoring key. It took the instructor about 10-15 minutes to interject comments into each student's presentation. Similar to grading papers, interjecting comments into the weaker presentations took longer than the stronger presentations. The videos and feedback were given to students within 4 to 8 workdays following the first presentation, and within 6 to 14 workdays following the second presentation. The feedback included the summarized written instructor comments and rubric evaluation. Upon receiving their videos and feedback, students then had up to a week to complete the guided reflection.

One section of students received interjected feedback, while the other section of students received only a raw video of their performance and individually met with the instructor in face-to-face meetings 1 to 4 workdays after receiving the videos. Students were expected to bring their completed self-reflection to the face-to-face meeting. During these meetings, the instructor played and reviewed the videos with the students, stopping at specific points to discuss their performance. Each of these meetings lasted about 20-30 minutes. The same procedure was followed for both presentations, except that the sections were reversed with respect to which section received interjected feedback and which received face-to-face feedback after the second oral presentation.

During the final lesson of the semester, students completed a paper version of the subjective feedback questionnaire in class. No names or other identifying information were collected with the feedback, and it took approximately fifteen minutes for students to complete.

Data analysis

In order to test the impact of interjected feedback compared to face-to-face feedback, we compared the two groups with respect to their performance and subjective feedback. For the performance comparisons we had a blind scorer use the rubric to assign a total score of up to 40 points, based on his analysis of four components (Content, Organization, Style, and Responds to Audience, each scored up to 10 points). For the subjective Likert-scale feedback, 1 point was assigned for "Not Useful," "Disagree," and "Not Likely," 5 points were assigned for "Very Useful," "Strongly Agree," and "Very Likely," and intermediate scores were given (2, 3, 4) for the progressively intermediate response options (e.g. minimally useful, somewhat useful, and useful, respectively). We categorized the open-ended responses based on common themes that appeared.

Results

Performance Data—Blindly Scored Video Presentations. For each rubric component as well as the total score, we performed a 2 (Group: interjected feedback first or face-to-face feedback first) x 2 (Presentation: first or second) mixed ANOVA, with group being the between variable and time being the within variable. For all components and the total score, there were significant main effects of time, $p < 0.01$ and there were no main effects for groups or interactions.

However, Accomp was higher for the group receiving face-to-face feedback first, $t(24) = 1.6$, $p = 0.06$ (one-tailed), and it significantly correlated with the scores on the students' second presentation, r (26) = 0.52, $p < 0.01$. Therefore, we calculated difference scores based on the students' amount of improvement for each of the four component scores and the total score, and then for each we performed a single-factor, 2-level ANCOVA using Accomp as the covariate. In all cases, the adjusted means led to increases in the difference score for the interjected feedback first group, i.e. they showed more improvement between presentations, and decreases in the difference score for the face-to-face feedback first group. For the component of style, the adjusted difference between the groups was nearly significant F (1.25) = 3.43, $p = 0.08$, with the interjected feedback first group showing more improvement across the two presentations than the face-to-face feedback first group (mean improvement = 1.5 compared to 0.6, respectively).

Student Questionnaires: Likert-Scale Responses. In most cases, the average Likert response scores indicated no difference between the two groups regarding the usefulness of the rubric criteria, the usefulness of viewing the videos on their own, the usefulness of the summarized feedback, or the usefulness of the self-reflection. In all these cases, there was generally good agreement that each of the aspects of the course feedback process were useful, with the average scores ranging from 3.8 up to 4.4 on the 5-point scale.

However, both groups indicated that they watched their videos more times after the first presentation (mean = 1.53) than the second presentation (mean = 1.28). A 2 (Group: interjected first or face-to-face first) x 2 (Presentation: first or second) mixed ANOVA for the number of times to watch their videos beyond what was required to complete the reflection assignment and meeting with the instructor showed no group difference and no interaction, but a significant effect of presentation, $F(1,29)=5.24$, $p=.03$.

Further, there was a clear indication that, regardless of group, the students believed the face-to-face feedback (mean = 4.5) was more useful than the interjected feedback (mean = 3.8). Thus, we also performed a 2 (Group: interjected first or face-to-face first) x 2 (type of feedback:

INT or F2F) mixed ANOVA for reported usefulness of feedback. Regardless of what type of feedback they received first, students significantly rated face-to-face feedback as being more useful, $F(1, 28) = 8.33$, $p < 0.01$. There was no main effect for group nor was there a significant interaction.

Student Questionnaires: Open-Ended Responses. Students' open-ended responses showed several clear trends that help us better understand the performance and Likert-scale data, and that hint at pros and cons for both the interjected and the face-to-face feedback. These comments did not show different trends based on group (whether students received interjected feedback first or face-to-face feedback first).

First of all, the vast majority of students indicated the general value of having the videos to review. For example, several noted the helpful aspect of being able to view themselves as if they were a member of the audience rather than the presenter, for example: "Seeing yourself is completely different sometimes than how actually you pictured yourself doing," and "I was able to put a critique to an actual picture and see what everyone else saw." Many students also made generic comments about how watching their videos helped them improve: "I learn and improve better analyzing my own video on my own time," "a lot of the times you don't notice the mistakes or habits you make so the video allowed me to break bad habits and improve," and "I think [receiving a videotaped presentation] was the most useful feedback I have ever received on an oral presentation."

As noted above, all students were required to watch their videos prior to answering the guided reflections. Thus, for both presentations, all students watched their video in private first, and then half of them met with the instructor for face-to-face feedback. Similar to our pilot study, many students in this study also found it uncomfortable to watch themselves, even if at the same time they noted how beneficial it was to have the video recordings. Example comments include, "it's very difficult to watch yourself in the video when you're not presenting and it helped give insights that I otherwise would not have noticed," "It was awkward to watch myself, but it did help accentuate idiosyncrasies during the presentation," and "Allowed me to see firsthand what I was doing wrong. But it was the most awkward thing ever."

More explicitly related to the interjected feedback, many students appreciated the targeted nature of the interjected comments. Example responses include, "helps identify exactly where mistakes were made," "showed specific instances to focus on," "showed positive/negative things right as they were happening," and "that was the most useful part. I saw that I did something well or poorly and I was immediately notified from the instructor's point of view." Less positively, a small number of students indicated that the interjected comments were distracting, or that they struggled with the abbreviations used (Table 1). For example, the interjected comments were a "little confusing - had to go back and look up the symbol key a couple of times and it took away from watching the video."

With respect to the face-to-face feedback, students especially appreciated the depth of explanation when they met face-to-face with the instructor. One student stated, "I understood more when the feedback was face to face and more personal—I also learned more about the concepts," and another student echoed this sentiment in the following comment: "[Face to face] was the best feedback, even better than the written feedback because we were able to really dissect my argument and discuss the pros/cons and how to improve on other points that could have been made." Others noted that the face-to-face feedback "Gave a chance to go deep into the reasoning behind deficiencies and find a way to fix them," and "helped explain in detail what I could do better."

Discussion

Our study was designed to investigate how the use of interjected comments into video recordings of student oral presentations would impact student presentation skill development relative to the use of a video recording and face-to-face feedback sessions with the instructor. A motivation for this work was to create effective practices for students' development while managing the load on the instructor. We carefully embedded the oral presentation feedback within several other best practices for student development (e.g. use of a rubric, guided reflection to link the feedback with the presentation objectives). Overall, our data indicate significant positive effects of using video recordings, with respect to both the development of students' presentation skills, and their self-reported attitudes. Both groups improved between their first and second presentations. However, other than for the rubric component of Style, where the group receiving interjected feedback first showed a strong trend for greater improvement, there were no significant differences between groups.

The trend toward a difference in improvement for the Style component may be due to the fact that this component focuses on more overt behaviors (e.g. "enunciation, pace, volume, eye contact, body movements") that can be targeted more precisely within the video recordings. In contrast, the rubric components of Content and Organization tap into higher-level aspects of the presentations that aren't easily targeted within a few frames. Further, even when some aspect of organization or content was indicated using the interjected video comments, the nature of the comments, i.e. the use of short abbreviations such as "L" to indicate something about the logic of the sequence, meant that they were not deeply informative. This example highlights the inherent tension present when balancing instructor load and quality feedback; although short abbreviations are a time-saving mechanism for instructors, they can lead to the commonly held student perception that instructor feedback is vague and difficult to apply (Price et al., 2010).

The students' self-reported feedback offers further insight into the relative benefits of the interjected and face-to-face feedback. Regardless of whether they received the interjected feedback first or second, students reported great value in having the videos to review, and they showed an appreciation of the targeted nature of the interjected comments. Thus, even though providing students raw videotapes without anything more may not help them to reflect as effectively as possible (Cooper, 2005), the videotapes still serves as a tangible artifact that allows them to view themselves in the third-person, and therefore helps them gain a new perspective on their performance. Furthermore, students' positive reception of the interjected comments aligns closely with Gibbs and Simpson who stated that feedback needs to be specific to be effective (Gibbs & Simpson, 2004).

Many students also explicitly noted the discomfort they felt when watching themselves, which suggests another benefit of the interjected comments: the feedback review process can be private rather than shared with the instructor. However, these same students also clearly indicated that they especially appreciated the face-to-face feedback because of the depth and personalized nature of that feedback. In fact, for both groups, face-to-face feedback was rated as significantly more useful than the interjected feedback. These preferences highlight, perhaps, an unstated assumption that face-to-face meetings resulted in more "quality" feedback as opposed to interjected feedback which was merely "timely" (Winter & Dye, 2004; Chang et al., 2012). One reason why students may have felt that the face-to-face meetings resulted in more quality feedback is that they had the opportunity to direct the discussion and engage in a dialogue with the instructor, even if ultimately, they would have gained the same information through both interjected and summarized comments.

As we move forward in considering how best to use an instructor's time and resources, we should examine the disconnect between students' perceptions and performance. After all, what we as instructors ultimately want is an improvement in student performance. If the face-to-face feedback really was so much more useful, why didn't the group receiving face-to-face feedback on the first presentation show more improvement from the first to the second presentation than the group that first received interjected feedback, especially with respect to the areas of content and organization? Is it really worth an instructor's time to meet individually with each student and review the videotapes?

One interpretation is that the Content and Organization components of performance are more cognitively challenging and require more practice to improve. In contrast, the Style components may be more tangible and easier for students to develop in a shorter time period. Thus, even if the face-to-face feedback was more useful for students, the amount of improvement seen from one presentation to the next would not be significant. In future semesters, development of the Content and Organization components could be further enhanced by requiring more than two oral presentations in order to build in more opportunities for practice. Alternately, the addition of writing assignments that specifically link to the presentations would allow instructors to give more detailed, interjected written feedback on the content and organization in the papers without needing to meet face-to face with the students

However, we don't want to forget about the benefit of the interjected comments on the Style component development. The style and real-time audience interaction aspects of oral presentations are what distinguish oral presentations from written papers, and are the skills we hope to develop in our students. In the interest of not overloading instructors perhaps the more overt nature of the style elements could be captured through a peer-review process. The benefits of peer review (e.g. engagement, greater depth of processing for the reviewer and receiver of the review) are well documented for aspects of assignments to which students can bring some expertise (e.g. Lundstrum & Baker, 2009). Throughout their lives, students have watched many others give presentations, and they should be able identify stylistic aspects of presentations that were less effective, especially if given specific guidance on behaviors to note. What most students are not practiced at is watching and analyzing their own performances, especially during more awkward moments where the human tendency is to look away. Thus, students could be assigned to review a small number of classmates' video recordings and, using style guidelines, insert the interjected feedback. The students could then watch their own videos with interjected feedback in the privacy of their own room. While instructors could still note stylistic aspects during face-to-face feedback, they would be able to focus the majority of their discussion on the higher-level aspects of content and organization. In this way, instructors could maximize their time and efforts, as well as leverage peer critiquing to provide students a well-balanced assessment of oral presentation skills that does not unduly emphasize content over command of the oral medium or oral medium over content (Cooper, 2005).

Important to note is that all students received their feedback as part of an intentional course design that incorporated best practices, such as multiple presentations to support a developmental focus (Gibbs & Simpson, 2004; Price et al., 2010), the integrated use of the rubric (Stevens & Levi, 2005; Andrade, 1997), and structured reflection activities that "forced" students to watch the video at least once and explicitly state steps they would take for improvement (Nicol & Macfarlane-Dick, 2006). In other words, the use of video technology in and of itself is not a complete solution (Hooper & Rieber, 1995). An intentional course framework ensures more explicit overlap between the students' and instructors' understanding of the same goals (Nicol & Macfarlane-Dick, 2006). Without this framework of best practices, it's likely that the positive impact of any feedback would be decreased. In fact, the significant decrease in the number of video viewings following the second presentation compared to the first presentation suggests that students often only move beyond the required minimum when there is a follow-on assignment that could clearly benefit from use of the feedback (Gibbs & Simpson, 2004; Price et al., 2010). All of our best practices helped ensure that our feedback process was not a one-way one street from instructor to student, but rather, part of a process involving both traditional and non-traditional forms of feedback that required active engagement from the students as well as the instructor.

Also with respect to technology use, it's important to acknowledge that the use of technology provides challenges (e.g. server space to store videos, purchase costs, time to learn to use applications) (Kovach, 1996), and that, despite rapid evolution, the technology resources are often not designed with instructors' goals in mind. In our study, the time it took the instructor to provide the interjected comments, post-production, using the abbreviations shown in Table 1 was about half the amount of time taken when meeting face-to-face. Thus, we did achieve a substantial time savings. However, at 10-15 minutes per video, the total amount of time was still substantial. Thus, while we personally believe there is a benefit to recording student oral presentations and to interjecting comments to give feedback, especially for style elements, we cannot ignore some of the costs also associated with the approach.

In sum, students crave feedback (Robert & Anthony, 2003), and our study indicates that video feedback can help support student development of oral presentation skills. Our results also suggest that, depending upon the specific skills an instructor wants to develop, i.e. style versus content and organization, different types of feedback might be more effective. Further, our student feedback responses suggest that access to even just the raw video without comments or a face-to-face meeting could provide some benefit, especially with respect to general aspects of the presentation, because the videos provide students with the perspective of a member of the audience. Thus, an instructor might choose different feedback options for different oral presentations throughout the semester in order to balance developmental progress and load on the instructor. Alternately, through the use of interjected comments by peers (for style elements) and face-to-face by instructors (for the higher-level content and organization elements), both types of components could be effectively developed without expecting an instructor to provide both types of feedback. Crucially, we should all remember that feedback needs to implemented with best practices in mind, so that students have reason to and take the time to review and process the feedback. Without student engagement in the feedback and development process, no development will occur.

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Classroom clickers offer more than repetition: Converging evidence for the testing effect and confirmatory feedback in clicker-assisted learning

Amy M. Shapiro[1] and Leamarie T. Gordon[2]

Abstract: The present study used a methodology that controlled subject and item effects in a live classroom to demonstrate the efficacy of classroom clicker use for factual knowledge acquisition, and to explore the cognition underlying clicker learning effects. Specifically, we sought to rule out repetition as the underlying reason for clicker learning effects by capitalizing on a common cognitive phenomenon, the spacing effect. Because the spacing effect is a robust phenomenon that occurs when repetition is used to enhance memory, we proposed that spacing lecture content and clicker questions would improve retention if repetition is the root of clicker-enhanced memory. In experiment 1 we found that the spacing effect did not occur with clicker use. That is, students performed equally on clicker-targeted exam questions regardless of whether the clicker questions were presented immediately after presentation of the information during lecture or after a delay of several days. Experiment 2 provided a more direct test of repetition, comparing test performance after clicker use with performance after a second presentation of the relevant material. Clicker questions promoted significantly higher performance on test questions than repetition of the targeted material. Thus, the present experiments failed to support repetition as the mechanism driving clicker effects. Further analyses support the testing effect and confirmatory feedback as the mechanisms through which clickers enhance student performance. The results indicate that clickers offer the possibility of real cognitive change in the classroom.

Keywords: clickers, feedback, clicker-assisted learning, knowledge acquistion

Personal response systems, commonly called clickers, have become common in thousands of classrooms nationally. They allow instructors to assess comprehension and memory for material by posing a question to the class (usually multiple-choice) that students answer with remote devices they bring to class. Questions and answers take as little as a minute or two to present and collect, and voting results can be displayed instantly in a bar graph. Understandably, educators and researchers have been interested in the technology's educational effectiveness. Generally speaking, the majority of studies have shown that clickers are effective in boosting attendance and participation (Beekes, 2006; Poirier & Feldman, 2007; Shih, Rogers, Hart, Phillis, & Lavoie, 2008; Stowell & Nelson, 2007) and learning outcomes (Kennedy & Cutts, 2005; Mayer et al., 2009, Morling et al., 2008; Ribbens, 2007; Shapiro, 2009; Shapiro & Gordon, 2012). Few studies have explored the cognitive mechanism through which clickers increase retention of lecture content, however. The focus of the present work was to better

[1] University of Massachusetts Dartmouth, Psychology Department, 285 Old Westport Road, North Dartmouth, MA 02747-2300, ashapiro@umassd.edu
[2] Tufts University

understand the cognition driving clicker effects. Specifically, the experiments presented here were designed to rule out repetition as the basis of clicker effects in fact-based learning, thereby supporting the hypothesis that the testing effect and feedback drive clicker effects.

There are several ways clickers may work to enhance memory for classroom material: (1) directing students' attention to material likely to be on exams, (2) repetition, and (3) the testing effect. The first possibility, that clickers "tip off" students about the instructor's judgment of important material, and therefore the content of exam questions, is a reasonable hypothesis. One might expect students to attend to those topics more in class and focus study effort on those topics. Greater attention in class and increased studying would both enhance exam performance. If the attention-grabbing hypothesis is correct, it would mean clicker questions do not directly enhance memory or learning. It would mean only that they are an effective means of directing learners' attention to particular topics. Repetition effects, the second possible way clickers enhance memory for classroom material, make the justification for clicker use similarly debatable. Repetition can be accomplished through online resources, readings or other assignments outside of class, without using any class time and at no cost to students. If clicker effects are attributable instead to the last possibility, the testing effect, it would indicate they have unique benefit in the classroom. Writing clicker questions and integrating them with class lectures does require a modest time investment. Once that is completed, however, clicker questions require little class time to administer, correct and enter to grade sheets. Indeed, the entire sequence of presentation, response, grading, recording and feedback all happens within seconds. As such, if clickers are due to the testing effect rather than repetition or attention-grabbing it would mean they offer unique benefit of enhanced learning during class time with very little investment of time or money.

Shapiro and Gordon (2012) were able to rule out attention-grabbing and found modest support for the testing effect during clicker use in a live classroom. In their study, a series of exam questions were targeted over the semester in two classes. Half the items in one class were targeted with clicker questions when the information was taught in class. The other half of the questions was targeted by attention alerts. They assigned the same items to the opposite conditions in the other class. This counterbalanced the assignment of each question to the experimental and control conditions, and created a situation in which each item served in both the clicker and attention conditions. Students did not get clicker questions about the information assigned to the attention condition. Instead, they were told that the information was very important and would be covered on the next test. The relevant information on the PowerPoint slide was also highlighted in red and was animated to flash. At the end of the semester students were given a survey that asked what directed their decisions about what to study. In spite of the fact that they reported studying the information targeted by the alerts more than that targeted by clicker questions, students performed as well or better on questions when a clicker questions was offered. In short, even when attention was explicitly drawn to specific information in class and studied more outside of class, answering a clicker question had an equal or greater effect on exam performance. That study did not rule out attention-grabbing as a contributing factor to clicker effects, but it did provide strong evidence that it is unlikely to be the sole source of clicker effects. The authors argued that the testing effect also underlies clicker effects.

Shapiro and Gordon (2012) were not able to rule out the possibility of repetition effects as the mechanism underlying clicker effects, however. Because they compared a clicker group to a no-clicker control group that was exposed to one presentation of the material, repetition is confounded with clicker use. Indeed, the majority of studies that report clicker effects compare clicker use with no clicker use, with no control for repetition effects (e.g., Mayer et al. 2009; Morling et al, 2008; Shapiro, 2009). At present, then, it is unclear whether the testing effect or simple repetition effects are driving clicker effects in the classroom. The present study was designed to address this question. We sought to determine whether the learning outcomes observed with clicker use are attributable to repetition. Before explaining the methodology, we provide a brief review on the research that explains these phenomena.

The Testing Effect and Repetition Learning

Karpicke, Roediger and others have documented that testing memory can enhance later recall or recognition better than an equivalent amount of additional study (Butler, Karpicke, & Roediger, 2007; Carrier & Pashler, 1992; Karpicke & Roediger, 2007a, 2007b, 2008; Roediger & Karpicke, 2006a; Szpunar, McDermott, & Roediger, 2008). In what has become the classic paradigm for investigating the testing effect, Thompson, Wenger, and Bartlings (1978) gave one group 3 study sessions followed by a delayed test (SSST). Another group studied the same information once and was then tested 3 times (STTT), the final test serving as the dependent measure after a 48 hour delay. On the final test, the SSST group forgot 56% of the material, as opposed to just 13% by the STTT group. This basic effect has been demonstrated using free recall (Jacoby, 1978; Szpunar et al., 2008), short-answer (Agarwal, Karpicke, Kang, Roediger, & McDermott, 2006) and multiple-choice (Duchastel, 1981; Nungester & Duchastel, 1982) tests and has been demonstrated with memory for word lists (Karpicke & Roediger, 2007a; Tulving, 1967), paired-associates (Allen, Mahler, & Estes (1969) and text (Nungester & Duchastel, 1982; Roediger and Karpicke, 2006a).

The cognition underlying the testing effect is not fully understood but some hypotheses have emerged and are currently under investigation. One possibility is that repeated testing creates conditions in which information is over-learned, a position argued by Thompson et al. (1978). Over-learning is an unlikely explanation of clicker effects, as it is improbable that offering a single clicker question in class can lead to over-learning. A more likely possibility is that testing strengthens the pathways leading to a stored memory more than additional study does (Bjork, 1975). Since study can be very passive (e.g., re-reading text passages or lecture notes), the more active nature of generating responses or comparing multiple-choice alternatives could reasonably offer greater opportunity for such enhancement. In other words, individuals are engaging in an activity that requires greater concentration during testing than some forms of study. Indeed, Bjork and Bjork (1992) have argued that there is a positive relationship between the level of effort required during testing and the strength of memory. As such, the effect may be a form of depth of processing (Craik & Lockhart, 1972).

Alternatively, testing may generate new routes to the memory trace, thus multiplying possible access points to the material (McDaniel & Masson, 1985). When memories are formed, information about the context and activities relevant to the material are also formed. Testing offers new perspectives and links to the information that may be sensitive to different memory cues than the connections formed during study. The latter possibility would take advantage of encoding specificity, as a pathway generated through testing is likely to be more easily accessed during later testing. An excellent and more extensive review of the testing effect is provided by Roediger & Karpicke (2006b).

Although the mechanisms underlying the testing effect are not fully understood, numerous investigations have demonstrated that the effect seems to be enhanced by feedback (e.g., Butler & Roediger, 2007; Hattie & Timperley, 2007; Kulhavy, 1977; Pashler, Cepeda, Wixted, & Rohrer, 2005; Sassenrath & Gaverick, 1965; Thorndike, 1913). Feedback can be confirmatory or corrective, and there is evidence that both types enhance later test performance (Butler, Karpicke, & Roediger, 2007; Kluger & DeNisi, 1996; McDaniel et al., 2007; Vojdanoska et al., 2010). Because clickers allow instructors to provide feedback with a simple button click within seconds of voting, feedback is widely used among clicker-adopting instructors. As a consequence, feedback is an important facet of clicker use to consider when questioning the reasons underlying clicker-mediated learning effects, particularly the testing effect.

It is important to note that the testing effect has been demonstrated in many experiments that did not employ feedback (see Kang, McDermott, & Roediger, 2007, experiment 1; Marsh, Agawal, & Roediger, 2009; Roediger & Karpicke, 2006a), so while there is the potential for the contribution of feedback effects during clicker-based learning, some other mechanism unique to testing appears to be working with or in addition to feedback. A study by Kang et al. (2007) underscores this point. After reading journal articles, subjects took either short answer or multiple-choice tests prior to a final memory test. Subjects did better on the final test when they took preliminary multiple-choice tests. When feedback was offered on the preliminary tests (in experiment 2), however, students taking the short answer tests did better on the final test. In sum, testing improved learning in Kang et al.'s study, but the addition of feedback altered something about the mechanism involved. The results are highly suggestive of some sort of interaction between the memory processes relevant during testing and feedback.

In spite of the fact that testing, especially with feedback, has been shown to enhance performance on tests more than study repetition, mere re-exposure to material alone can improve learning. The more times a student is exposed to a bit of information, the greater the likelihood he or she will retain it (e.g., Ebbinghaus,1913; Raney, 2003; Scarborough, Cortese, & Scarborough, 1977; Tulving, 1967). As such, it is certainly possible that clicker questions may improve retention for classroom content merely by re-exposing students to the material. In other words, clicker effects may simply be repetition effects, and that is a potential criticism of any experiment that demonstrates clicker effects by comparing clicker use with a no-clicker control. Thus, it is important to rule out repetition as the cause of clicker effects in order to strengthen the argument for classroom clickers as effective and worthwhile pedagogical tools.

The Present Study

Shapiro and Gordon (2012) concluded that the testing effect, not attention-grabbing, is responsible for enhanced learning with clickers in their experiment. Because they compared clicker groups to non-clicker control groups, as do most published studies on the topic, clicker use was confounded with repetition in their investigation. In the present two-experiment study we tested whether clicker effects are due, at least in part, to repetition.

Experiment 1 takes advantage repetition learning in order to determine the role of repetition in clicker effects. Specifically, if repetition is a significant source of clicker effects, clicker use should be subject to the *spacing effect*. The spacing effect (also called *distributed learning*) refers to the phenomenon in which rehearsal or re-exposure to material results in greater memory when a period of time is allowed to intervene between presentations (Benjamin & Tullis, 2010; Cepeda, Pashler, Vul, Wixted, & Rohrer, 2006; Glenberg, 1979; Hintzman, 1974). If clicker questions are more effective when offered after a delay of several days, it will indicate the questions are likely serving as a method of repeating exposure to class material. If the spacing effect is not evident, it will indicate that repetition is unlikely to be a significant factor in clicker effects.

In experiment 2, we compared a clicker group that received a single presentation of the material and a subsequent clicker question to a group that received a second presentation of the material in place of the clicker question. Because Shapiro and Gordon (2012) have found evidence against attention-grabbing as the reason for clicker effects, failure to support repetition in the present study would provide converging evidence that clicker effects are most likely attributable to the testing effect. We also took advantage of the clicker data to perform a secondary analysis on clicker performance to learn something about the role of feedback in clicker effects.

Experiment 1

The experiment was designed to determine whether the clicker learning effects demonstrated in prior studies are subject to the spacing effect, and thus attributable to repetition effects. We designed experiment 1 to compare exam question performance when clicker questions were asked immediately after in-class presentation of the material and when clicker questions were asked after a delay. If the spacing effect is in evidence, subjects should score higher on test items when clicker questions were offered 2-5 days after the material was taught in class, as compared with the same clicker questions offered the same day. Finding a spacing effect would indicate that clicker effects may be attributed, at least in part, to repetition. If the spacing effect does not emerge in the data, it would indicate that either feedback or the testing effect leads to cognitive change that can't be attributed to simple rehearsal. For this reason, an analysis of clicker question performance was conducted to determine the role of feedback apart from repetition.

Method

Subjects

Four hundred students enrolled in two sections of general psychology at the University of Massachusetts participated in the study. Students participated as part of their normal coursework, and earned participation points by correctly answering in-class questions. They ranged from freshmen to seniors and represented a range of disciplines offered at the institution. IRB approval was sought prior to beginning the study and a waiver was granted.

Materials and Procedure

The class covered 11 topics in general psychology and was taught as a typical lecture course with demonstrations and multimedia integrated into many of the lectures. PowerPoint presentations were projected onto a movie theater-sized screen. In-class clicker questions were integrated into the presentations, with individual slides dedicated to single questions. The iClicker system was used to allow students to make their responses to clicker questions.

Students were required to purchase their clickers (for $20-40, depending on whether they were new or bundled with the required text book).

Sixteen test clicker question/test item pairs were used as stimuli in the present study. Each clicker question was written to tap the same information as its targeted exam question. All clicker and exam questions were multiple-choice and were taken from Shapiro and Gordon (2012). The clicker question/test item pairs were spread throughout the semester, and across the four exams administered during the semester. Performance on the exam questions was the dependent variable.

All the targeted exam questions were included in the exams for both classes. The clicker question written for each targeted exam question was also given to each class. The timing of the clicker question presentation was manipulated as the within-subjects independent variable. When assigned to the "immediate" condition, clicker questions were given in class directly after the material was presented and any student questions were answered. When assigned to the "delayed" condition, the questions were given at the start of another class meeting, 2-5 days after the material was taught. Half the items were included in each condition for one class, with the other half included in the opposite condition for the other class. As such, each of the 16 experimental items was included in both the immediate and delayed conditions, and each subject contributed data to both conditions. Presentation of the relevant course material was the same in both conditions; the information was included on a PowerPoint slide. Identical "filler" clicker questions targeting material unrelated to the experimental items were offered to both classes, with the experimental items mixed randomly among them. Between 1-5 clicker questions (filler and experimental) were asked in class each day. The instructor projected the clicker questions onto the screen after soliciting and answering any questions from the students. Students were given 30-90 seconds to answer each question and a bar chart showing the percentage of the class to respond with each option was projected to provide feedback after voting was closed.

Exam and clicker question validation. Because a simple, no-clicker control condition would not allow discrimination between clicker and repetition effects, which is the purpose of this investigation, a no-clicker group was not included. For that reason, it was important to establish that the materials used in the present study do induce a basic learning effect. As mentioned, the sixteen clicker questions, and the corresponding exam questions for which they were written, were taken from Shapiro and Gordon (2012). The clicker question written for each exam question probed the same basic information as the test question, but was still unique. In their study, Shapiro and Gordon implemented a counterbalancing strategy wherein each of two classes was given clicker questions for half the targeted exam questions. For the other half of the questions, subjects were given no clicker question. For half of those in the control condition (see experiment 1), no special treatment was given to the material in class. For the other half, however, students were told the material was important and would be on the test (see experiment 2), creating a very conservative test of clicker learning effects. The methodology controlled for both item and subject effects, as each exam question was used in the control and clicker conditions and each subject contributed data to both conditions. Half the stimuli in the present experiment were taken from Shapiro and Gordon's experiment 1 and half from experiment 2. Thus, in order to establish that the item subset chosen for the present study does produce the basic clicker learning effect, the analysis from that experiment was re-run including only the subset of items chosen for the present study. Analyzed by subjects, a paired t-test revealed a significant effect of clickers on performance, $t(234) = 5.62$, $p < .0001$, $d=.37$. Students scored a mean of 68.9% (SD=18.7) correct on items when no clicker question was offered and 76.8% (SD=18.1) correct when a question was offered, more than an 11% performance increase. The results were also significant when analyzed by items, $t(15) = 4.29$, $p < .001$, $d=1.08$, with items answered correctly by 69.4% (SD=12.1) of subjects when placed in the control condition and 76.0% (SD=10.8) answering the same questions correctly when clicker questions were asked, an increase of almost 10%. Again, this is a very conservative test of the stimuli because half the items in the control condition were identified to students as material that would be on the test. In spite of the warning, clicker questions still significantly boosted exam performance.

Other measures of the stimuli were taken to ensure stimulus validity. Two independent content experts provided validation ratings of the stimuli. Both are professors of psychology that routinely teach introductory psychology. They rated each clicker and exam question on a 7-point scale for the following dimensions: (1) overall quality of the question, (2) relevance of the information targeted by the clicker/exam item pairs to the content and goals of an introductory psychology course, (3) the relationship between each clicker item and each exam question. The questions used in the experiment all scored a minimum rating and minimum mean of 5.0 by each rater on questions 1 and 2. The clicker/exam pairs met the same criteria on survey question 3. The relationship ratings between clicker questions and exam questions which were *not* intended as pairs were also analyzed. It was important that unpaired items were actually unrelated to ensure clicker questions were not enhancing memory for exam questions for which they were not written. All unrelated clicker/exam question pairs used in the present experiment scored a maximum rating of 2.0 among reviewers and had a mean rating of 1.5. The low ratings established the unlikelihood of "spillover" effects. That is, clicker questions were unlikely to affect performance on exam questions for which they were not intended.

Results and Discussion

Students who withdrew early from the course, those with attendance lower than 60%, and those who missed more than one exam were excluded from the data analysis. These students provided insufficient data for the within-subjects comparisons or were insufficiently exposed to the independent variable. The deletions yielded a total of 283 subjects in the analysis. Moreover, individual exam question data were removed from the analysis for students who were absent from class the day the targeted content was presented. Missing those critical classes meant missing the targeted content as well as their immediate clicker questions. Also, effects of the delayed clicker questions would be difficult to interpret for those cases. A maximum of 16 exam questions per subject was possible and these deletions resulted in a mean of 13.1 per subject. Out of a maximum of 283 student scores for each question, the deletions resulted in a mean of 229.6.

Paired *t*-tests were performed to compare performance between the immediate and delayed conditions. The results did not reveal evidence of a spacing effect. When analyzed by subjects, there was no significant difference between performance on exam items when targeted by immediate (M = 67.5, SD = 24.1) or delayed (M = 70.0, SD = 21.8) clicker questions, $t(282) = 1.73$, $p > .05$. No significant difference between the immediate (M = 67.4, SD=9.3) and delayed (M = 69.8, SD=11.7) conditions was revealed in the item analysis, $t(15) = 1.04$, $p > .05$. The mean discrimination index for the exam questions was 50.4.

Since there was no spacing effect, the data argue against repetition as a significant mechanism underlying clicker effects. If repetition isn't driving the effect, what is? A clue to the relevant processes may be gleaned by examining clicker question performance in the immediate versus delayed conditions. It makes intuitive sense that students would perform better on immediate clicker questions, as the information needed to answer the questions correctly has just been presented in lecture. In light of the fact that students performed equally well on later exam questions regardless of clicker question timing, however, if students did perform better on the immediate versus delayed clicker questions it would suggest corrective feedback is being used to improve test performance to some extent. Paired *t*-tests by items, comparing clicker question performance between immediate and delayed conditions revealed just that. Students scored a significantly higher percent correct on immediate clicker questions (M = 94.7, SD=9.1) than delayed (M = 83.2, SD=15.8), $t(281) = 10.99$, $p < .0001$, $d = .65$. The same result was found when analyzed by items, with the same clicker questions answered correctly more often when asked in the immediate condition (M=94.7, SD=5.1) than in the delayed condition (M=82.0, SD=18.3), $t(15) = 2.85$, $p < .01$, $d = .72$. Not only are the *t*-tests significant, but the effect sizes are quite robust. Despite such clear differences between immediate and delayed clicker performance, exam performance was not affected by conditions. As such, it stands to reason students were able to make some use of their performance feedback in the delayed condition to improve test performance.

The clicker performance analysis provides only indirect evidence about the effect of corrective feedback, however. A more direct test is possible by comparing exam question performance when the clicker questions were answered correctly versus incorrectly. If feedback is a primary factor in clicker effects, students should score equally on exam questions regardless of clicker performance as long as they are given feedback, as they were in the present study. If there is a significant difference, it would mean the effect of corrective feedback is limited and unlikely to account for the entire effect. To run this test, all subjects and questions in the delayed clicker condition were combined to create groups based on clicker performance. Because clicker performance was quite high in the immediate condition (95%), there were insufficient incorrect responses to compare with the correct responses, so the analysis was done only on the delayed clicker questions. Moreover, since exam question performance was deleted when the critical content lecture was missed, there are no cases in the immediate clicker condition in which students attended the content lecture but missed the clicker questions. The delayed condition, however, provides an important comparison group. That is, students who attended the critical content lecture but were not exposed to the delayed clicker question.

The limitations of corrective feedback effects are seen when performance is compared on test items for which students correctly versus incorrectly answered the corresponding clicker questions, or did not see the clicker questions. The mean of the 1422 exam questions included in the analysis, for which the corresponding clicker questions were correctly answered[3], was 72%. For the 286 exam questions, for which the corresponding clicker questions were incorrectly answered, the mean score was 63% correct. There were 191 unanswered, delayed clicker questions across subjects that did attend the critical content lecture (in other words, students who received the content in class but did not see the clicker question) and the mean score on the corresponding exam questions was 59%. Although the effect size was quite small, the difference was significant, $F(2, 1896) = 9.83$, $p < .0001$, $\eta^2 = .01$. A Scheffe's posthoc analysis revealed that

[3] With 16 items and 283 subjects, there were 2284 possible clicker responses in the immediate and in the delayed conditions. The number in the analysis is lower due to student absences.

exam question performance was significantly higher in the case of correctly answered clicker questions than incorrectly answered clicker questions, $p < .05$ (two tailed) and in the case of correct versus missed clicker questions, $p < .05$ (two tailed). The difference between exam question performance based on incorrect versus missed clicker questions was not significant, $p > .05$ (two tailed).

If corrective feedback were a primary mechanism through which clicker effects worked, there should be little or no significant difference on exam performance based on clicker performance. More importantly, incorrectly answered clicker questions should yield better performance than getting no clicker question at all. After all, if students are using clicker questions primarily to gain corrective feedback on their performance, one would expect to see evidence of widespread self-correction on the exam questions. The significant performance advantage by students getting the answer correct, in addition to the comparable exam performance of students getting a clicker question wrong and those unexposed to it, suggests corrective feedback was not particularly useful for students getting clicker questions wrong. The large differences in sample sizes and the rather low effect size, however, warrant caution about the strength of this conclusion.

Experiment 2

The purpose of experiment 2 was to provide converging evidence with experiment 1 that repetition is not the major source of clicker learning effects. The advantage of the methodology used in experiment 1 was that the presentation of immediate and delayed clicker questions seemed natural to students within the context of a live classroom. Taking advantage of the spacing effect in this way, however, only provided indirect evidence of the role of repetition. Experiment 2 addressed the question more directly by comparing exam question performance after the presentation of clicker questions or information repetition. Moreover, since the main evidence refuting repetition effects in experiment 1 was a nonsignificant result, experiment 2 was also designed to provide positive evidence (i.e., a significant statistical result) in support of our hypothesis.

Method

Subjects

Three hundred twenty students enrolled in two sections of General Psychology at the University of Massachusetts participated in the study. Students participated as part of their normal coursework, and earned participation points by correctly answering in-class questions. They ranged from freshmen to seniors and represented all five colleges across campus. IRB approval was sought prior to beginning the study and a waiver was granted.

Materials and Procedure

The same materials and procedure the same procedure was used as in experiment 1, but with one change. Instead of half the exam questions being targeted with delayed clicker questions in each semester, half were targeted with a second, immediate presentation of the material. In the clicker and repetition conditions, the same slide was used to present the information for the first time. In the clicker condition a clicker question followed the slide. In the repetition condition a second PowerPoint slide that presented the relevant information in a slightly different way from the first was presented in lieu of a clicker question. In this way, the effect of a second, novel presentation on exam question performance could be compared with the effect of a clicker question. A sample stimulus set from each condition is provided in Appendix A. In both conditions, the targeted information was presented verbally along with an accompanying slide. (In the Appendix A example, the targeted information was the role of the hypothalamus in hormone regulation.) In the repetition condition, the information was repeated with a new visual aid, while in the clicker condition students answered a question in lieu of seeing the second slide.

Results and Discussion

Students that withdrew early from the course, those with attendance lower than 60%, and those that missed more than one exam were excluded from the data analysis. This yielded a total of 290 students in the analysis. Paired *t*-tests were performed to compare performance between the clicker and repetition conditions. The results indicated significantly better performance in the clicker condition (M = 61.2, SD = 21.6) than in the repetition condition (M = 56.2, SD = 20.6) when analyzed by subjects, $t\ (289) = 3.417$, $p = .001$, $d = .20$. The effect was also significant when analyzed by items, $t\ (15) = 2.419$, $p = .029$, $d = .60$, with students performing better on items when the relevant content was presented with a clicker question (M = 60.7, SD = 10.4) rather than with a second presentation (M = 55.2, SD = 12.0).

The results of experiment 2 converge with those of experiment 1 to support the hypothesis that clicker questions do not enhance retention of classroom material merely because they act as a second presentation of information. The 5-point increase in subject performance (from 52.2 to 61.2) in the subject analysis represents a performance increase of 8.9%. The effect size is rather small, however. The 5.5-point increase in the item analysis represents a 10% increase and a moderate effect size, however. While these results can't rule out any role of repetition in clicker effects, they do provide compelling evidence that repetition is not the major source of the effect.

General Discussion and Conclusions

Shapiro and Gordon (2012) reported evidence that clicker effects are not attributable to drawing students' attention to certain material. That study was not able to rule out repetition effects as an underlying cause of clicker-enhanced learning, however. The present study addressed that possibility and demonstrated that repetition is unlikely to be a major contributor to the effect. In doing so, it provides converging evidence with Shapiro and Gordon that the testing effect is likely to underlie clicker-enhanced learning.

In a secondary analysis of experiment 1, we tried to determine whether feedback has a role in clicker effects, since feedback is an important variable in the testing effect. The conclusions we were able to draw from those analyses are suggestive of some role of feedback, but do not paint a clear picture. The delayed clicker group performed worse on clicker questions than the immediate group but performed equivalently on exam questions, suggesting that corrective feedback helped. However, a comparison of exam question performance when students correctly versus incorrectly answered the clicker questions revealed students performed better on exam questions when they got clicker questions right. Indeed, students answering the clicker question incorrectly performed only as well on the exam questions as students that were not exposed to the clicker question at all. These results suggest corrective feedback had a weak effect on exam performance. Any conclusions drawn from the latter result, however, are mitigated by the rather low effect size. On balance, then, the present results are suggestive of some role of corrective feedback in clicker-based learning. That conclusion is compatible with the large literature on the role of feedback in the testing effect. Certainly, feedback should be an important area for future inquiry.

Regardless of the feedback question, the results do converge with Shapiro and Gordon (2012) to support the conclusion that the testing effect is the most likely mechanism underlying clicker effects. The notion of testing itself causing cognitive change is supported by the extensive work of Karpicke and colleagues (e.g., Karpicke & Roediger, 2007a; 2008) on the testing effect. As Bjork (1975) suggests, the act of retrieving memories may strengthen the memory trace. Moreover, it may create new routes to memories that are more easily invoked during exams, with the context common to testing situations acting as a retrieval cue.

The present experiment was designed to test clicker use for enhancing fact-based learning alone. As such, the results do not support clicker use for problem-solving, application, or deep-level understanding of the material. Within the context of fact-based learning, however, the present results are of practical importance for educators and students. As such, we can offer some concrete suggestions for effective use of clickers in the classroom. Specifically, we suggest that important factual content be targeted with clicker questions. The questions should be written specifically to require memory retrieval of the targeted information. We also suggest the questions be worded clearly and in a way that maximizes students ability to correctly answer the questions. After all, if the testing effect is at the heart of clicker-enhanced learning, the goal should be to encourage students to correctly recall the correct information from memory, thereby activating the testing effect.

Finally, clickers seem to invoke cognitive change in the classroom that is unique. If clicker effects were attributable to repetition or attention-grabbing, their value might be dubious. After all, there are many avenues through which to provide repetition or enhance attention inside and outside the classroom. Having demonstrated that clicker use affects cognitive change attributable to the testing effect (and quite possibly to feedback, as well) the present results support clickers as a unique and valuable pedagogical classroom tool. Given the relatively low cost in terms of classroom time and equipment expense, the evidence in support of their educational benefit suggests they do offer real value to students and instructors.

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Appendix

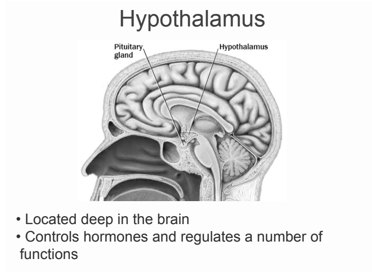
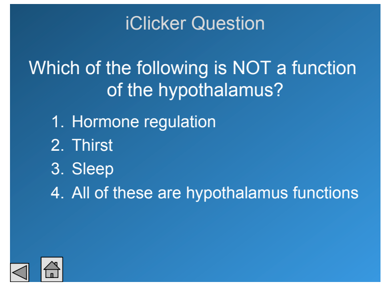
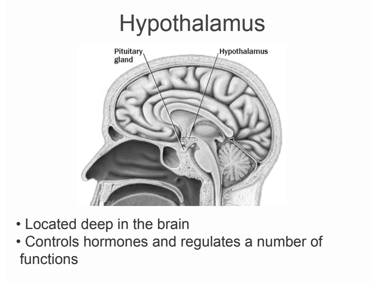
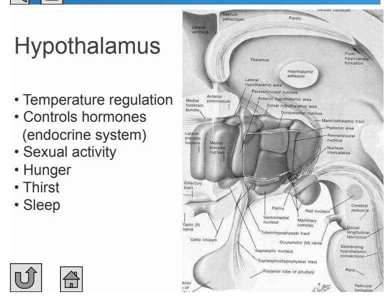
Appendix A. Sample Stimulus Set.

Sample item in the clicker and repetition conditions, reproduced in grayscale.

TARGETED EXAM QUESTION:

Which brain structure exerts considerable influence over the secretion of hormones throughout the body?

A. the hypothalamus
B. the amygdala
C. the hippocampus
D. the thalamus

EXPERIMENTAL CONDITION	FIRST PRESENTATION	SECOND PRESENTATION
Clicker		
Repetition		

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Tools for high-tech tool use: A framework and heuristics for using interactive simulations

Daniel A. Rehn, Emily B. Moore, Noah S. Podolefsky, and Noah D. Finkelstein[1]

Abstract: As the use of computer-based science simulations in educational environments grows, so too does the need for research on productive use of simulations. This paper presents ways to create effective assignments that accompany an interactive simulation in a variety of educational environments. A framework that supports the creation of assignments with simulations in any environment is provided, as well as a set of heuristics, or strategies, for how to create assignments based on the particular environment and simulation being used. Case studies are provided to illustrate implementation of the heuristics, and how the heuristics can be used to promote productive use of a simulation.

Keywords: assignment design, heuristics, physics, simulations, science, middle school, undergraduate

I. Introduction.

The use of computer technology in educational environments is now widespread and continues to grow. Classrooms throughout the country, in both K-12 and college settings, are currently using computers as an educational tool. As such, teachers are now confronted with the question of how to use this tool productively to educate students.

In science education, a common use of computers in the classroom is to run science simulations (National Research Council, 2011). There are a variety of educational science simulations available for use, and each has a unique set of features that allow users to interact with the simulation interface and the scientific content illustrated by the simulation. For the purposes of this paper, we focus on a class of simulations referred to as *targeted simulations* (Clark, Nelson, Sengupta, & D'Angleo, 2009).

Targeted simulations are stand-alone simulations designed to cover a particular topic in a scientific discipline. For instance, a single targeted simulation may cover gravitational forces in physics; another simulation may cover acids and bases in chemistry. The amount of time needed to learn how to use a targeted simulation is minimal, as the controls are designed to be intuitive and easily manipulated. Examples of targeted simulations include PhET ("PhET," 2012a), Physlets (Christian, n.d.) and TEAL ("TEAL," 1999) simulations. It is useful to separate targeted simulations from simulations that allow users to modify the code of the simulation itself, such as NetLogo (Wilensky, 1999) and StarLogo ("StarLogo," 2008).

Historically, research on student use of targeted simulations has been conducted in interview settings (Adams et al., 2008; Adams, Paulson, & Wieman, 2008; Podolefsky, Perkins, & Adams, 2010), small classrooms (Keller, Finkelstein, Perkins, & Pollock, 2005; Podolefsky, Rehn, & Perkins, 2013), and large classrooms (Finkelstein et al., 2005; Moore, Herzog, & Perkins, 2012). Research of student use in interview settings can allow for fine-grained analysis of students' actions, point out common ways that students use the simulations, reveal any bugs in

[1] Department of Physics, University of Colorado, 390 UCB, Boulder, CO 80309, daniel.rehn@colorado.edu

the simulation, and provide a measure of how engaging the simulation is by itself. Classroom studies can allow for pre-test/post-test test comparisons with a larger sample size for statistical analysis. On one hand, the interviews provide moment-to-moment analysis of how students use a simulation; on the other, the overall effect of a simulation on classroom learning gains can be investigated. However, interviews do not provide a direct view of how students use a simulation in classrooms, and findings of learning gains from classroom studies do not necessarily reflect how much a student could learn from a simulation in an interview setting.

Embedding a simulation into an educational environment different from an interview setting changes many variables that can influence simulation use. For example, in a classroom setting, students might talk to one another about the simulation. Such an action clearly cannot be accounted for in interview settings with only a single student present. Factors such as students sitting in groups or individually, the number of students per computer, the time allotted to the activity, and so on, will influence how students use a simulation.

In this paper, we take the view that in any educational environment, there exist a multitude of variables that influence how students use a simulation, and ultimately, how this educational tool impacts student learning. As educators, our goal is to facilitate productive use of a simulation. In order to do this, we first need to define productive use of a simulation. However, due to the variety of contexts in which simulations are used, and the number of teachers with different goals and standards for their students, we intentionally allow for some ambiguity in our definition of 'productive use'; what a 5th grade teacher considers productive use of a simulation may be different from what a college instructor considers productive use. In the case studies below, we provide contextualized examples of productive use in two different environments. For now, a brief definition can provide some insight into what we mean, in general, by productive simulation use:

> *Productive use of a simulation occurs when students use the simulation as a tool to engage with the underlying physical principles that govern the simulation's behavior.*

In creating an educational context that supports productive simulation use for students, the design of an assignment that accompanies the simulation stands out as particularly important. Not only does the assignment influence and structure students' use of the simulation, but also is one aspect that an instructor can directly control. Writing an assignment to accompany a simulation can be a challenging task, as the assignment must be written for the particular context in which it will be used. To illustrate the interrelations between the context and assignment design, we first describe a framework that includes context elements and how each can affect simulation use.

We then present a set of *heuristics* – research-based strategies for assignment development. These heuristics are intended to provide insight into how assignments can be written, and in doing so, can help frame the ways we can think about writing assignments in a given context. Of course, which heuristics to implement will vary depending on the particular class of students, e.g., the topic being covered and the amount of teacher guidance desired during the activity.

The reason for presenting both a framework and a set of heuristics is to provide an actionable set of tools that can directly aid in assignment creation. A framework alone provides an overarching view of how different components of an educational context fit together, but does not provide direct strategies for integrating the components. At the same time, heuristics can provide actionable strategies, but do not provide an overarching view of the context or where they fit in relation to different components. By using both a framework and a set of heuristics, we can provide both an overarching view of the context and actionable strategies for integrating the components of a context.

In the second half of the paper, we provide two case studies that investigate simulation use in two radically different environments. The first case study involves the use of a quantum tunneling tutorial in a college-level modern physics (sophomore/junior level) classroom. In this case study, the tutorial used was not designed with the heuristics in mind, and the assignment did not promote productive use of the simulation in that context. The results of the study, however, provided insights into what heuristics might be implemented in the next design of an assignment using the same simulation. In the second case study, we discuss the use of a molecule-building simulation in a middle school science classroom. In this case study, the assignment utilized several heuristics, and students engaged in productive use of the simulation. The second study demonstrates the effective application of the heuristics, their applicability to a wide range of environments, and highlights approaches that span from middle school to college.

II. Framework for Simulation Use in Educational Settings.

In an educational context where a simulation is used with an assignment, we identify three elements that influence how students use the simulation. These three elements are: the Simulation, the Assignment, and the Environment. One could consider the simulation and assignment as a part of the Environment, but for the purposes of this paper, we separate out Environment to refer to anything other than the Simulation or Assignment. A more detailed definition of Environment is given later in this section.[2]

The three elements together should support students in productive use of the simulation. The following framework shows the interrelations among these elements and how they affect student use of the simulation. Note that we draw from work on mediated cognition (Vygotsky & Cole, 1978; Cole, 1996) and situated cognition (Lave & Wenger, 1991; Hutchins, 1995) in the creation of this framework. This framework consists of a ‘situation’ level of context that brings students into coordination with the simulation, assignment, and environment (Dewey, 1938; Cole, 1996; Finkelstein, 2005). Also note that, while no teacher is present in this framework, we do acknowledge the importance of the teacher and his or her influence on the educational context. The teacher can have direct control over, and/or interaction with, each of the elements in the framework.

In Figure 1, the elements with arrows pointing directly towards the ‘Student use of simulation’ element indicate that that element can directly influence how students use the simulation. The outer arrows indicate influences among the elements. For example, the Simulation and Environment both influence how the assignment is created. Additionally, these arrows contain the word ‘Heuristics’ to indicate where the heuristics included in this work can be used. With this general picture in mind, we now elaborate on the details of each of the elements and their interrelations.

[2] To be consistent with notation, we capitalize words that refer to an element of the framework itself. For example, in referring to the Assignment, we are really referring to the element of the framework labeled “Assignment”. When referring to an assignment (not capitalized), we are referring to an actual, real-world assignment, not the framework element Assignment.

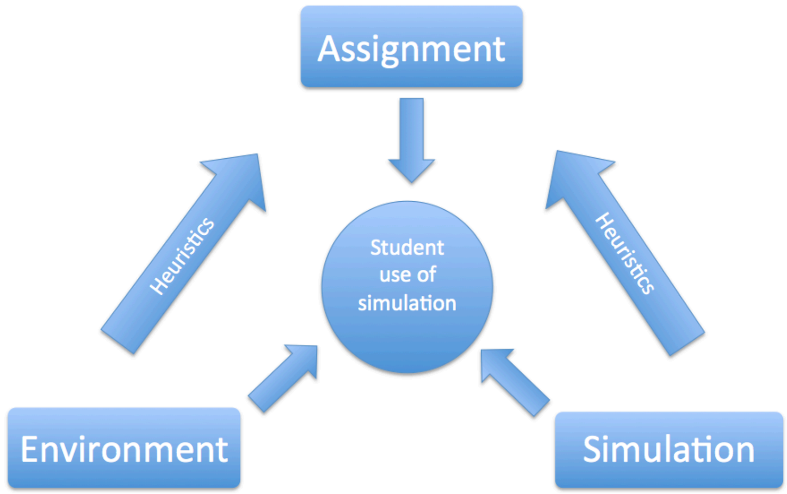

Figure 1: Framework for analyzing student use of an assignment and simulation within a context. Heuristics are implemented in the arrows shown.

From the Simulation element, an arrow points towards the 'Student use of simulation' element, indicating that the simulation itself influences student simulation use. A 'Heuristics' arrow points from the Simulation element towards the Assignment element, indicating that the development of the assignment depends on the simulation. Therefore, based on the features of the simulation, heuristics can be chosen to aid in the development of the assignment.

From the Environment element, an arrow points toward the 'Student use of simulation' element, indicating that the environment influences student simulation use. A 'Heuristics' arrow extends from the Environment element towards the Assignment element, indicating that the development of the assignment depends on the environment. Therefore, based on the specifics of the environment, heuristics can be chosen to aid in the development of the assignment.

We consider four components that characterize essential elements of the environment that shape (and are shaped by) students' use of the simulations in guided lessons. Note that, although the Simulation and Assignment may be considered a part of the educational environment, we keep these as separate from the environment strictly for utility. The entire framework together constitutes an educational 'context', while the environment is an element of that context, which we categorize as:

1. **Other students**: For any particular student using the simulation, other students serve as resources within that environment.
2. **Material resources**: Resources students might use during the course of the activity, e.g., pencils, physical (toy) models, and information written on chalkboards.
3. **Environmental organization**: Organization of resources in the room, e.g., where students are in relation to each other and the location of any material resources, such as the computers or smart board.
4. **Environment norms**: Typical behaviors and/or habits established in environments that influence student behavior during the activity, e.g., teacher expectations, and common actions or behaviors of the student.

From the Assignment element, an arrow points towards the 'Student use of simulation' element, indicating that the assignment influences student simulation use.

This framework provides a view of the learning context in which a simulation is used, allowing us to see areas in which interrelationships exist. These interrelationships allow us to see where the heuristics for assignment development can be useful. We now present the heuristics and examples of their implementation.

III. Heuristics.

Through case studies conducted in a variety of learning contexts and a review of relevant literature on simulation use, we constructed a set of six heuristics that can be useful when developing assignments for use with a targeted simulation. We do not consider this list of heuristics to be exhaustive; additional studies may help to expand and/or refine the current set.

> Heuristic 1. Use the simulation to ***coordinate multiple forms of representation***.
> Scientists utilize a variety of methods to visualize, interpret and communicate about physical phenomena, e.g., formulas, graphs and diagrams. (Roth & Radford, 2011; Kohl & Finkelstein, 2008). With an understanding of the ways scientists coordinate representational formats, one can design an assignment that supports students in coordinating these different representational formats, and therefore aid in their understanding of a particular phenomenon. This can be implemented by specifically asking students to relate formulas or graphs to what is shown on the simulation, or build this more implicitly into the assignment by asking them to complete a task that requires them to coordinate multiple representations.
>
> Heuristic 2. Use the simulation to ***mediate discussion.***
> Conversation and discussion is crucial for students learning science (Smith et al., 2009). Simulations can help students to communicate with one another by providing a common visualization to refer to and build meaning upon (Otero, 2004). This heuristic can be implemented by building student-to-student dialogue into the assignment itself. One may provide prompts that encourage students to discuss features shown in the simulation, negotiate meaning, or find a common interpretation. Depending on the context, discussions mediated by the simulation may arise naturally. For example, if a teacher consistently encourages students to discuss with one another during classroom activities, students may discuss the simulation without additional prompting.
>
> Heuristic 3. Set up ***game-like situations*** and take advantage of ***explicit and implicit challenges.***
> Consistent with prior work on “play” (Rieber, 1996; Vygotsky, 1978) and “messing about” (Hawkins, 1974), utilizing challenges or games within the simulation can encourage students to investigating a particular phenomenon. This heuristic can be implemented by writing challenges into the assignment itself, or by allowing students freedom to interact with a game-like situation or challenge built into the simulation itself.

Heuristic 4. Focus on ***illuminating cases.***
Scientists often talk about investigating limiting cases when exploring a problem; e.g. investigating the behavior of a system after a short or long period of time or at distances short or far away. Scientists may also refer to touchstone problems (Redish, 2003; Kuhn, 1962) that give outstanding insight into a particular concept. Simulations can often illustrate (or animate) what happens in certain interesting cases. This heuristic can be implemented by using prompts that encourage students to make use of interesting cases in the simulation, e.g., “What happens when friction is turned off?” or “What happens if the initial velocity of the object is infinitely high?”

Heuristic 5. Ask students to ***re-create or re-present features*** on the simulation.
The act of writing or drawing representations in the simulation can help students make sense of and internalize what the simulation shows. This heuristic can be implemented by prompting students to re-present features of the simulation on their own paper. Such prompts will allow them extra time to study what is shown, and possibly realize features that would have otherwise been missed.

Heuristic 6. Use ***“Predict, Observe, Explain”*** methods.
The “Predict, Observe, Explain” style of inquiry is found in studies done by the University of Washington (Shaffer & McDermott, 1991), and has been discussed in both theory and classroom studies (White & Gunstone, 1992; Mintzes, Wandersee, & Novak, 2005; Kearney, 2004). This heuristic can be implemented by starting a section of an activity with a prediction prompt. The prompt might describe a scenario in the simulation and ask students to think about what will happen when they observe or interact with the simulation in a particular way. Following this, students observe the scenario (run or use the simulation), and are then prompted to explain what they saw and/or resolve any differences between their predictions and observations.

IV. Application of Framework and Heuristics.

In the following two sections, we describe the implementation of the framework and heuristics in designing and analyzing two assignments in two radically different environments. The first of these is the use of a quantum tunneling assignment in a college-level modern physics course and the second is the use of a molecule-building assignment in a middle school class. The quantum tunneling assignment involves advanced physics concepts, which we describe briefly below, while the molecule-building assignment involves foundational concepts, including the meaning of coefficients and subscripts in chemical formulas. Although the content is very different in these two studies, the heuristics are applicable in both situations.

Both studies support the utility of the heuristics, though for different reasons. The quantum tunneling study involved the use of two different assignments, one with a simulation (the *sim-assignment*) and one without a simulation (the *no-sim-assignment*). In this case, the *sim-assignment* was *ineffective* in supporting productive student use of the simulation. In contrast, student engagement with the topic in the *no-sim-assignment* showed aspects of the productive student discussions and sense making that we would hope for from a *sim-assignment*. The productive aspects of the *no-sim-assignment* were used to gain insight into the heuristics that could be implemented in an updated version of the *sim-assignment*. Use of the updated *sim-assignment* was observed to support productive student use of the simulation. The molecule-building assignment supported productive student use of the simulation. Reasons for this can be understood through analysis of the heuristics present in the assignment. While the molecule-building assignment was used in a middle school classroom, a similar implementation process can be followed in a college level classroom. Student difficulties with chemistry content – specifically, molecular formulae – have been well documented at the college level (Davidowitz, Chittleborough, & Murray, 2010; Sanger, 2005), and our findings therefore likely apply to college level chemistry courses.

Both studies use simulations developed by the PhET Interactive Simulations project ("PhET," 2012a). These targeted simulations are research-based, and specifically designed to be intuitive, easy to use, and to focus on specific science concepts (Finkelstein, Adams, Keller, Perkins, & Wieman, 2006). While the following studies strictly use PhET simulations, the heuristics implemented are applicable for assignments involving other targeted simulations.

V. Case Study: Quantum Tunneling.

Here we provide an example of the use of the heuristics and their relationship to the accompanying framework in the context of an hour-long quantum tunneling tutorial. This tutorial was offered in a lower-division modern physics course at a large state research university. This course was designed for sophomore or junior-level engineering students who have a strong background in basic mechanics, electricity, and magnetism, but who may not have studied quantum mechanics in a previous course.

During participation in the reformation of a similar course, the PhET Interactive Simulations project at the University of Colorado designed the *Quantum Tunneling and Wave Packets* simulation ("PhET," 2012b) to illustrate the nature of tunneling (McKagan et al., 2008). In this study, a subset of students (11 out of approximately 150 enrolled students) volunteered to participate in an hour-long tutorial outside of the regular class time. This tutorial was held in one afternoon, in a small classroom. Students worked on the assignment in groups of two to three.

We begin by giving a brief overview of the topic of quantum tunneling. This section provides the minimum amount of background necessary for understanding the design of the assignment and simulation, and can be skipped for those already familiar with the conceptual foundations of quantum tunneling. We then describe the study by elaborating on each element in the framework presented in Section II: the simulation used, the students' environment, and the assignments. Finally, we analyze issues with the assignments, and conclude with a discussion of why the *sim-assignment* failed and how the heuristics were used to develop a new version of the assignment.

A. Tunneling Overview.

Here we summarize the content covered in the *sim-assignment* and *no-sim-assignment*. Further details on the assignment content can be found in Appendix 1. Both assignments explore the physical situation of an electron moving towards the end of a wire, separated from another wire a short distance *L* away, shown in Figure 2. In this case, the gap between the two wires serves as an energy barrier, so that the electron needs some energy to escape the left wire and move to the right wire.

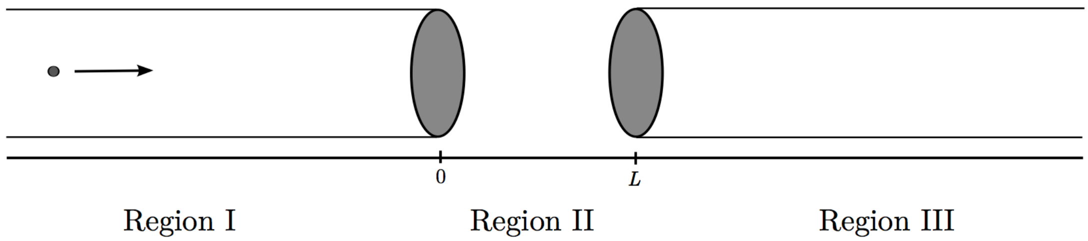

Figure 2: Schematic of an electron approaching the end of a wire separated a distance L from another wire.

The energy barrier between the wires can be represented with a plot of energy vs. distance, shown in Figure 3. Additionally, the total energy of the electron can be plotted on the same graph. For the purposes of the assignment, we focused on two cases, one where the electron has more energy than the gap (shown in green) and one where the electron has less energy than the gap (shown in red).

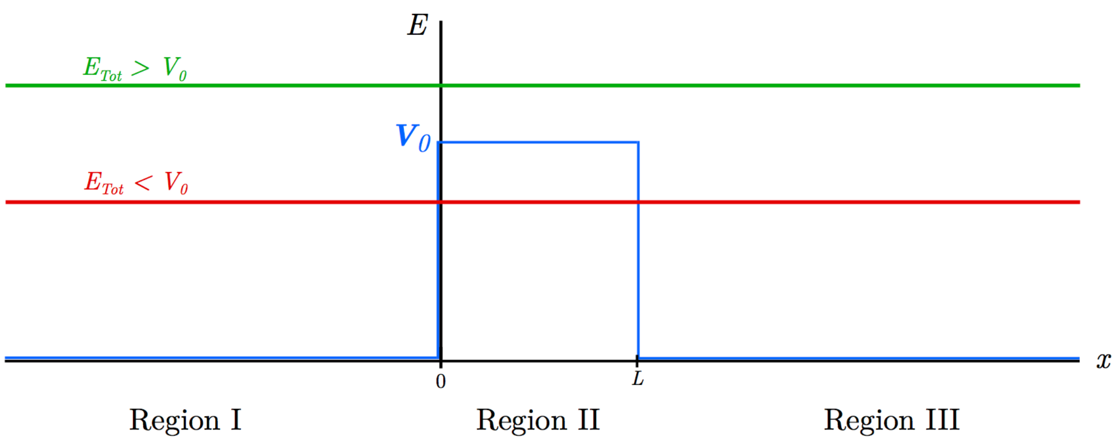

Figure 3: Quantum potential barrier, representing the potential energy, V_0, inside the wire gap.

An analogous example in classical mechanics is a ball rolling up a ramp with some total energy. In this case, if the total energy of the ball is greater than the energy of the barrier, the ball will roll over the ramp. On the other hand, if the total energy of the ball is less than the energy of the barrier, the ball will roll back down the ramp, returning to the side it came from. This situation is depicted in Figure 4.

Unlike the intuitive behavior of the ball rolling up a ramp, the electron's behavior is more complicated, due to the wave-like nature of quantum particles. Instead of behaving as a classical particle, the electron is spread out as a wave. Because it acts as a wave, some of its 'wave function' is reflected off the barrier and some of it is transmitted through the barrier. Thus, unlike the case of a classical particle with less energy than the barrier, the electron with less energy than the barrier still has a probability of making it through to the other side. Classically, this is like a ball passing through the ramp itself and continuing to travel on the other side, hence it is called 'tunneling.'

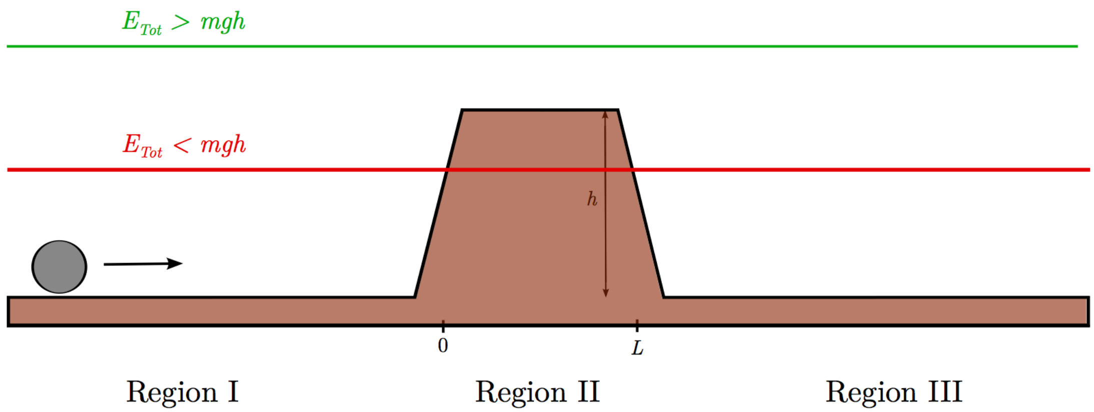

Figure 4: Classical energy barrier for a ball rolling over a frictionless ramp.

B. Simulation.

The simulation used in the *sim-assignment* contains three plots, shown in Figure 5. The top plot shows the potential barrier provided by the wires and total energy of the electron, similar to Figure 3. The middle plot shows a graph of the wave function, along with its time-dependence as it oscillates and moves towards the barrier. The bottom plot is a graph of the 'probability density', which is a measure of how likely the electron is to be found in each of the three regions. On the right-hand side, various parameters can be adjusted to change or illustrate different properties of the wave function.

Note that students can adjust the energy values on the top plot and see, in real time, how their actions affect the values of the wave function and probability density in the plots below. Other than the zoom-in/zoom-out buttons, the middle and bottom plots do not have any adjustable controls; therefore, the only way to change the wave function or probability density is to change the energy values on the top plot. This is a unique and important feature of the simulation, as it provides a productive constraint to what students can do with the simulation, and suggests how some of the heuristics might be implemented. For example, a challenge prompt for this assignment might be, "How do you make the wave function go to zero on the right side of the potential barrier?"

C. Environment.

The students' environment during the tutorial can be characterized using the four criteria listed in Section II. Below, we provide a brief description of each.

1. **Other students**: Eleven students participated in this study, including 10 male students and 1 female student. The activity was voluntary; students were offered pizza as a benefit for participating. The students received lectures on quantum tunneling previously in class and had worked on a homework set concerning quantum tunneling, though they had not worked on a tutorial covering the subject. During the tutorial, students demonstrated some familiarity with the subject, though none showed clear mastery. Students also showed some familiarity with each other, and did not appear hesitant to talk to each other. Nonetheless, four students did not speak frequently during the activity.

2. **Material resources**: Aside from the simulation, the teacher, and the assignment, students did not use any outside resources to complete the tutorial. A chalkboard was available, though it was not used.
3. **Environmental organization**: Two groups of three students used the *no-sim-assignment*. These students were situated at a large table, so that they functioned more as a single group of six. One group of two students and second group of three students used the *sim-assignment*. Each of these groups was given a laptop to access the simulation, and each group worked at a separate table. One of the students in the *sim-assignment* group of three frequently talked to the *sim-assignment* group of two, diminishing the distinction of two separate groups using the *sim-assignment*.
4. **Environment norms**: The students had likely taken introductory physics at the same university, where tutorials are commonly used. In the introductory physics environment, student groups are expected to put forth effort into understanding the material, to progress independently (without prompting from a teacher) and to ask questions of each other or the teacher when needed. These were the same expectations for the students who participated in this study.

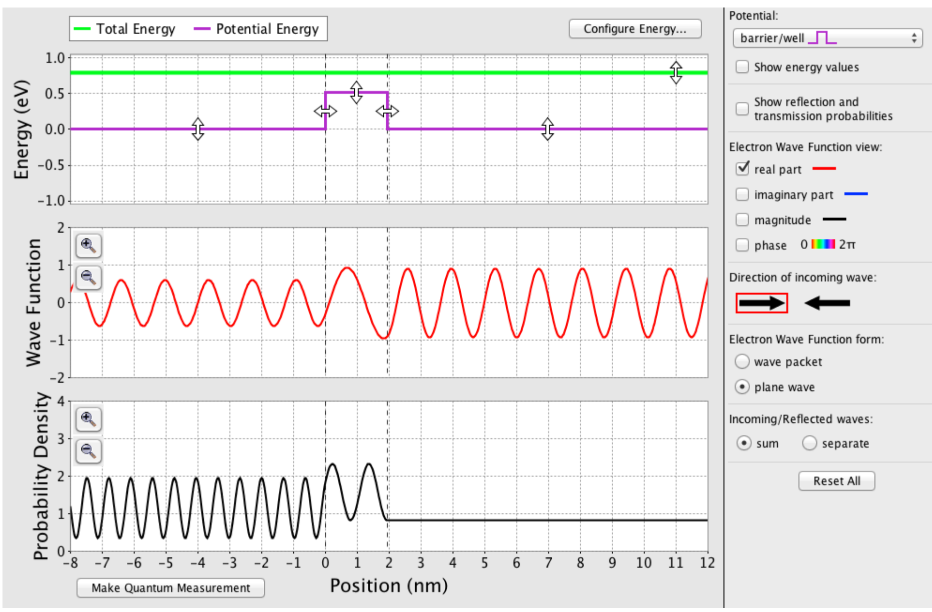

Figure 5: Interface of the *Quantum Tunneling and Wave Packets* PhET simulation.

The data collected in this study consists of audio recordings of the *sim-assignment* groups and the *no-sim-assignment* groups. Two audio recorders were used, one for *sim-assignment* groups and one for the *no-sim-assignment* groups. In total, three voices were present in the *sim-assignment* group's recording, while four voices were present in the *no-sim-assignment* group's recording. The remaining students (two from each recording) did not talk loudly enough to be heard. Additionally, field notes were taken.

D. Assignments.

In addressing this quantum phenomenon, the *sim-assignment* and *no-sim-assignment* followed the same basic structure. Each assignment starts with the same introduction in which students are asked to answer questions about a ball rolling up a ramp. Specifically, the assignments ask about the probabilities of the ball being found in regions 1, 2, or 3 separately with energy $E < V_0$ and energy $E > V_0$ (see Figure 4). After this, the assignments diverge in the types of questions asked, with the *sim-assignment* introducing the use the PhET simulation. Both assignments cover content in the following order: the case of the electron with $E > V_0$, followed by the electron with energy $E < V_0$. The full assignments can be found in Appendix 1.

E. Issues with the assignment: Discourse.

Student engagement with the topic of quantum tunneling differed significantly with the two assignments. Students using the *no-sim-assignment* explored the underlying physical principles of quantum tunneling in greater depth than those using the *sim-assignment*. In retrospect, it is clear that the heuristics were not implemented in the *sim-assignment*, while some of the heuristics were implemented in the *no-sim-assignment*. Based on the findings from these assignments, we created an updated *sim-assignment* that was more effective in supporting productive student use of the simulation.

Students using the *sim-assignment* engaged in less conversation, asked fewer questions of each other, and the questions they did ask were not as focused on conceptual understanding as were the questions asked by students using the *no-sim-assignment*. In total, the three students using the *sim-assignment* raised 27 questions, while the four students using the *no-sim-assignment* raised 90 questions. The types of questions asked by the students using the *no-sim-assignment* were strongly centered on the underlying physical principles of quantum tunneling. The types of questions asked by the students using the *sim-assignment* were strongly centered on what the simulation interface was showing, without emphasis on the underlying physical principles.

One example of the differences in student questions can be seen by comparing student discourse during the '$E < V_0$' section of both assignments. Students were asked what the probability of finding the ball in each region of its path is (see Figure 4). This was done partly to show that the quantum and classical cases of $E > V_0$ are roughly the same; that is, when the ball or electron wave function is located in the potential barrier, they move more 'slowly' and the probability of finding either one in that region is, on average, greater than in the other two regions separately.

However, this analogy breaks down in the case of $E < V_0$, since the classical ball can never be located in regions 2 or 3, whereas the quantum particle can be found in those regions. Both assignments address this point, but the ensuing discussion in the *no-sim-assignment* group was markedly different than that of students in the *sim-assignment* group. The *no-sim-assignment* group was asked to sketch what the wave function of the electron would look like in all three regions, while the *sim-assignment* group was asked to discuss the wave function they saw in the PhET simulation. When the *no-sim-assignment* group attempted to graph the wave function on their assignments, the following discussion arose:

> **S1**: "The reasoning we used before, at least I did, was that because the velocities were slower in the [potential barrier], then it had a higher probability of being found there. So if they're equal, they should have an equal probability and their amplitudes should be equal, right?"

> **S2**: "Right, well that makes sense in terms of equations, but like he said, I'm not sure you can think of it in a classical way, like ½ mv^2."
> **S1**: "I know, I know that [lower amplitude in region 3] is what it should be, but I want to be able to prove it to myself."

This type of reasoning is what we hoped students would engage in when trying to sketch the wave function. They knew from previous instruction that the wave function in region 3 should be lower than in the other two regions, but they struggled to prove to themselves why. In contrast, the students using the *sim-assignment* showed no similar reasoning. Instead of being asked to draw a wave function, the question on the assignment was: "What type of function do you see in region 1 and 3?" When answering this in reference to the wave function in region 3, they said:

> **S3**: "That one is still sine right? Like if you decrease it is it still sine or is it always zero?"
> **S4**: "Well this is technically still a sine wave."

These questions, which were strictly about what was shown on the simulation and not about the underlying physical principles that describe the simulation's behavior, are representative of nearly all questions that the *sim-assignment* students asked during the tutorial. It was clear from an analysis of both the field notes taken during the tutorial and a transcription of the audio recordings that the students using the *sim-assignment* were less engaged in exploring the underlying physical principles of quantum tunneling than the students using the *no-sim-assignment*.

F. Issues with the assignment: Guidance.

Another issue with the *sim-assignment* was the use of overly guiding questions. An example of this occurs in the part of the assignment dealing with $E > V_0$:

> Now widen the width of the wire gap (where V>0) to 3.5 dashed lines wide. How does the wavelength of the wave function in this region compare to the wavelength in the region to the left?

Asking overly guiding questions led to several negative effects. First, it prevented students from exploring the simulation. In observing students, there was little open-ended exploration of the simulation and instead, their use of the simulation generally consisted of reading the assignment, setting up the simulation in a particular way, and then leaving it until the next question prompted them to change another parameter. Overall, this indicated that there was little 'engaged exploration' while using the simulation, which is a crucial element of productive investigation of the physical principles embedded within the simulation itself (Adams, Paulson, & Wieman, 2008; Podolefsky, Perkins, & Adams, 2010). Second, the overly guiding questions caused students to wait for the tutorial to provide instructions on what to do next. Often, the term 'cookbook' is attributed to assignments that tend to focus on task completion, rather than on conceptual development (Singer, Hilton, & Schweingruber, 2005). Third, the overly guiding questions in the *sim-assignment* limited student conversations. Since the tutorial told the students how to set up the simulation, there was no discussion about how the simulation could or should be used. This prevented conversations from occurring about what the underlying physical concepts were and how the representations of these concepts in the simulation could or should be used to respond to the assignment prompts.

G. Relationship to heuristics and framework.

The failures of the *sim-assignment* can be understood by noting that there was a misalignment between the design of the assignment and the framework outlined in this work – the development of the Assignment had not been effectively influenced by the design of the Simulation. The overall result was that the assignment did not effectively support students in productive simulation use. To develop an improved *sim-assignment*, we would first explore the simulation, and based on properties of the simulation, choose certain heuristics to implement in writing the assignment.

On the other hand, the *no-sim-assignment* showed indications of success in promoting productive engagement with the quantum tunneling topic. Present in the *no-sim-assignment* are Heuristic 1 and the 'Predict' component of Heuristic 6. The *no-sim-assignment* asked students to coordinate the mathematical solutions of the electron's wave function in each of the three regions with a graph of the solution that they had to generate on their own. Had the *sim-assignment* used the simulation as a tool for observing the actual solution to the Schrödinger equation, and then explaining the differences between the actual solution and their predicted graphs, more conceptual discussion of the nature of tunneling might have occurred.

In retrospect, it is easy to see where the design of the *sim-assignment* went wrong. Asking students to set up the simulation in specific ways and answer questions about what they saw was an attempt to help them make connections between what was shown on the simulation and the underlying physical principles of quantum tunneling. However, because this particular simulation is a graphical representation of the mathematics involved in representing tunneling, asking students only about what they saw, rather than what the graphical representations mean, cued students to discuss only the mathematics rather than the underlying physical principles. Thus, it is clear that this assignment did utilize the features of the simulation in a useful way.

A strategy for designing an improved version of the *sim-assignment* could be:

1. Write out what productive use of the simulation could be in this environment. In this case, productive use occurred when students were investigating the physical principles that determine the simulation's mathematic representations.
2. Write out a list of the features of the simulation:
   a. Dynamic plots of mathematical solutions to the Schrodinger equation
   b. Adjustable parameters of potential height, potential width, etc.
3. Consider the environment students are to be situated in:
   a. Groups of 2-3 at tables
   b. Students sharing a computer
   c. One instructor present in classroom
4. Based on 2 and 3, choose certain heuristics to implement in writing the assignment:
   a. Understanding the features of the simulation requires some knowledge of the solutions to Schrodinger's equation in the three regions. Therefore, Heuristic 1 (Use the simulation to ***coordinate multiple forms of representation***) could have been used.

b. Students work in groups, so Heuristic 2 (Use the simulation to ***mediate discussion)*** can also be used. Students could be prompted by the assignment to "Discuss what is shown on the simulation" and to "Work together to generate a plot of the wave function."
c. There are particular scenarios in the simulation that are challenge-like, so Heuristic 3 (Set up ***game-like situations*** and take advantage of ***explicit and implicit challenges)*** could be used. One challenge could be "Find a potential width for which the wave is completely transmitted".
d. Heuristic 6 (Use ***"Predict, Observe, Explain"*** methods) can be used in a way similar to the *no-sim-assignment*. The updated *sim-assignment* could start by asking students to "Draw a wave function (a prediction phase), look at what the solution actually is on the simulation (observation phase), and explain the differences between their plots and the simulation (explain phase)." This will likely result in promoting discussion around the simulation itself – Heuristic 2.

These strategies, including use of the heuristics, have now been implemented in an updated quantum tunneling tutorial that uses the simulation for an upper-division quantum mechanics course, instead of a lower-division modern physics course. The full updated assignment and a general outline of how the assignment was written can be found in Appendix 1.

While the findings from an initial trial are not presented in detail in this paper, observations of use of the updated assignment indicate that the implementation of the heuristics led to the intended types of productive simulation use. An analysis of screen capture and audio files of the use of the updated assignment indicated that students were engaged with the simulation and that their discussions were concerned primarily with investigating the underlying physical principles of the simulation itself. Often, students found that their prediction of the wave function was in disagreement with the simulation, and turned to the mathematics involved to clarify discrepancies. Additionally, the screen capture files indicate that the challenges built into the simulation led students to interact with the simulation in an exploratory manner, e.g., adjusting the potential barrier and width, in order to find the cases of maximum transmission, reflection that were asked about in the assignment.

VI. Case Study: Build a Molecule.

In this case study, we present the use of an assignment that employs three heuristics and is aligned with the elements of the provided framework. The assignment was developed by a middle school teacher, in collaboration with a researcher from the PhET Interactive Simulations project, for use in a middle school classroom. The assignment design contributed to a set of assignment guidelines (Adams et al., 2008) and strategies that the teacher and PhET researchers found useful when creating assignments of this type (Perkins, Moore, Podolefsky, Lancaster, & Denison, 2011). Although the activity was not specifically designed with the heuristics in mind, the heuristics and framework can be used to understand the effectiveness of the assignment. Furthermore, this assignment addresses content that spans a wide range of audiences, including college students who struggle with understanding molecular formulae (Davidowitz, Chittleborough, & Murray, 2010; Sanger, 2005).

The assignment utilized the *Build a Molecule* PhET simulation ("PhET," 2012c) in three 5th grade classrooms, each with approximately 20 students. The goals of the assignment were for students to distinguish atoms from molecules, to determine the meaning of coefficients and subscripts in chemical formulas, and to coordinate across pictorial and symbolic molecule representations (e.g., 2D and 3D pictorial representations and chemical formulas). The simulation had been designed to address these specific learning goals.

First, we present an overview of the context, including details on the simulation, environment, and assignment as in the framework in Section II. The assignment section also describes how the heuristics are embedded within the activity. We then present an analysis of student use of the simulation, highlighting how the activity promoted productive student use of the simulation.

A. Simulation.

The *Build a Molecule* simulation provides an intuitive interface on which users can drag atoms from buckets and connect the atoms to build molecules. The simulation has three tabs that students can explore, starting with the "Make Molecules" tab, where the simulation design focuses student interaction on the building and collecting of single molecules, e.g., N_2. In the "Collect Multiple" tab, simulation design focuses student interaction on building and collecting multiple molecules, e.g., $2SO_4$. The, "Larger Molecules" tab provides an open play area, where students are encouraged to build larger molecules and to create their own challenges (e.g., to create the largest molecule they can) by being given many atoms and a large space to build within.

The "Build Molecules" and "Collect Multiple" tabs of the simulation provide 'goal' molecule boxes on the right-hand side. When a student builds a molecule listed as a 'goal', an outline appears around the corresponding 'goal' box. Students can then drag the molecule they built into the 'goal' box, collecting that molecule. The 'goal' boxes provide encouragement for students to make sense of the molecule formulas. Students must correctly interpret the letters and subscripts in the molecule formulas to build the molecules listed in the 'goal' boxes.

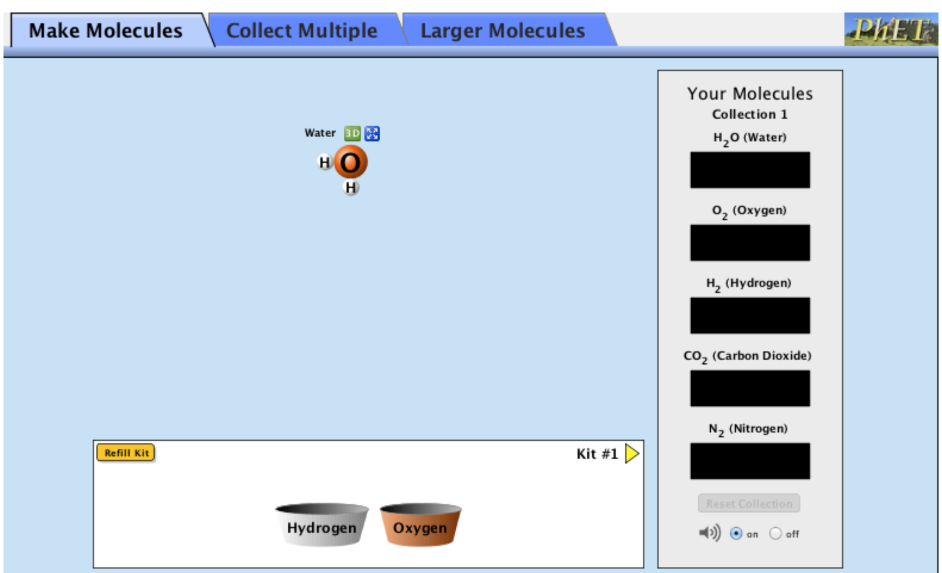

Figure 6: Interface of the *Build a Molecule* PhET simulation. Goal boxes are located on the right. Atoms are dragged from the buckets at the bottom onto the play area above.

B. Environment.

The students' environment during this activity can be described by defining each of the four characteristics listed in Section II:

1. **Other students**: Each student had a laptop and was encouraged to work with their neighbor to complete the assignment. Throughout the activity, students talked to their neighbors about the simulation and how to accomplish the challenges in the assignment (which corresponded to the 'goals' designed into the simulation). Additionally, the teacher facilitated the pacing of the assignment, asking students to complete the first few assignment prompts using the "Make Molecules" tab, then prompted students to move onto the next assignment prompts using the "Collect Multiple" tab, etc. The teacher sometimes called students to the Smart Board to demonstrate and explain to the class how they completed a goal in the simulation. This was often followed by a brief class discussion.
2. **Material resources**: Other than the simulation and assignment, the Smart Board is the primary resource students interacted with.
3. **Environmental organization**: Students were situated in groups of four to five. Everyone in the room was able to see the Smart Board.
4. **Environment Norms**: Students were familiar with using simulations and doing in-class activities similar to this one. The teacher generally requires that students pay attention when someone is talking at the Smart Board, and also makes sure that individual students are staying on task during the assignments. In general, students in the class follow these norms.

In addition, it is useful to point out that the teacher played an important role in facilitating the class in using the assignment and simulation. Generally, the teacher paced the students through the assignment, indicating when to transition to the next assignment section and when to discuss the current section as a class. We do not describe in detail the 'facilitation' heuristics that the teacher used in this paper, however we acknowledge that her facilitation contributed significantly to the success of the assignment.

C. Assignment.

The assignment used with the simulation emphasized three primary learning goals, which students read aloud at the beginning of class:

1. Describe the difference between a chemical name and a chemical formula
2. Distinguish between subscripts and coefficients in a chemical formula, and understand what each means
3. Use pictorial representations of molecules to generate chemical formulas

In addressing these goals, the assignment contains three sections, each corresponding to a tab on the simulation. The 'Make Molecules' section of the assignment begins by asking students to build molecules and write down the names of the molecules they made. This provided an opportunity for students to explore the simulation, with minimal time spent writing. After this, the assignment asks students to fill out a table, shown in Figure 7.

While only two rows are shown in Figure 7, the assignment contains six rows, prompting students to analyze six different molecules. This question demonstrates use of Heuristic 1, 3, and 5. Heuristic 1 (Use the simulation to ***coordinate multiple forms of representation***) is present by prompting students to write the molecule name, formula, and draw a picture of each molecule they find. Heuristic 5 (Ask students to ***re-create or re-present features*** on the simulation) is implemented by asking students to draw and write the three different representations for each molecule. The implementation of Heuristic 3 (Set up ***game-like situations*** and take advantage of ***explicit and implicit challenges***) is implemented in a more indirect way than Heuristic 1 and 5. The question shown above does not present a game-like challenge, but the open structure of the question facilitates play with the simulation itself, which does have an implicit challenge built in. The simulation allows for students to build molecules, collect molecules, and to complete collections – resulting in student access more goal molecules. By asking students to write down the names, pictorial representations, and chemical formulas of individual molecules, the question encourages that they complete the implicit challenges designed into the simulation itself.

2. Molecule Names and Chemical Formulas:
   a. Compare the name and chemical formula for some molecules:

Molecule Name	Drawing	Chemical Formula

Figure 7: Question taken from the "Make Molecules" section of the *Build a Molecule* assignment.

While the "Make Molecules" tab contains chemical formulas with subscripts, the 'Collect Multiple' tab contains molecule formulas with coefficients and subscripts. In this section, students are building multiple molecules, and must distinguish between subscripts and coefficients for the first time. The assignment addresses the differences with the question shown in Figure 8.

3. Make Many
   a. Fill all the collection boxes and then complete the questions for each Goal.

Goal: $4H_2$	
Draw it!	
What does the big '4' in $4H_2$ mean?	
What does the little '2' in $4H_2$ mean?	

Figure 8: Question format for the 'Make Multiple' portion of the *Build a Molecule* assignment.

While only one question set is presented in Figure 8, the assignment contains four similar question sets, asking students to analyze three other chemical formulas in addition to $4H_2$. Like the question in the 'Make Molecules' section of the assignment, this question implements Heuristics 1, 3, and 5. Students must coordinate representations between the formula ($4H_2$), the pictorial representation of that formula, and then describe what the subscripts and coefficients mean. Again, they are asked to draw and write features of the simulation by drawing the molecules. In order to complete this prompt, they are encouraged to take advantage of the implicit challenge inherent in the simulation itself; by collecting the 'goal' molecules in the simulation students could ensure that they answered the assignment questions correctly.

D. Analysis of Student Use.

During each class, 4-6 students' computer screens were recorded using screen capture software, with audio recordings from the computer microphone. We present excerpts of one student's interactions with the simulation in the 'Collect Multiple' section of the assignment – representative of the types of interaction we observed students having. Pre-tests and post-tests were given to students to assess student learning from the simulation activity. Students performed at a much higher level on the post-test compared to the pre-test, and we present example scores, as well as example student responses on the two tests as indicators of the assignment's effectiveness.

During the 'Collect Multiple' section of the assignment, one student, who will be called George, showed clear productive use of the simulation. The 'Collect Multiple' tab on the assignment starts with $2CO_2$, $2O_2$, $4H_2$, and $2NH_3$ as 'goal' boxes. At this point, George had finished using the 'Make Molecules' tab of the simulation, showing competence in constructing individual molecules. Upon starting on the 'Collect Multiple' tab, George had quickly built an O_2 molecule, dragged it to the 'goal' box, and then moved on to building $2CO_2$. George had initial difficulty with this challenge, first creating C_2O_2, and then arranging the atoms in different configurations, shown in Figure 9. After spending 50 seconds on this challenge, George moved on to the other goal boxes, next building one H_2 molecule and one NH_3 molecule, dragging both to the 'goal' boxes within 30 seconds.

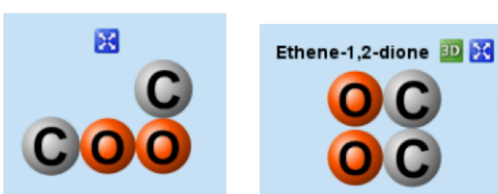

Figure 9: George's first and second attempts at building $2CO_2$.

Next, George went back to working on $2CO_2$, again creating a C_2O_2 variant – ethene-1,2,-dione, shown in Figure 9. George then began to play in what appeared to be a random way with the C and O atoms, and eventually created one CO_2 molecule and dragged it to the 'goal' box. However, George did not yet appear to understand the meaning of the coefficients at this point. Next, he built another CO_2 molecule and a molecule that looks similar to CO_2 right next to it, shown in Figure 10. However, instead of dragging the CO_2 molecule to the 'goal' box and completing the challenge, George created a yet larger molecule, C_2O_4 (also shown in Figure 10), and attempted to drag this to the $2CO_2$ box. After being rejected from moving this to the goal box, George said, “What!” with some frustration in his voice.

George continued to try to complete this goal box, but got stuck yet again when trying to build C_2O_4 in a different configuration, shown in Figure 11. Next, he separated this into two molecules that each resembles CO_2 (also shown in Figure 11), when a student sitting next to him, who will be called Jeff, made a suggestion for George.

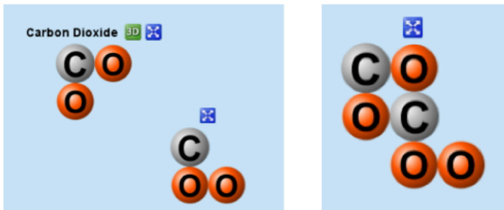

Figure 10: George’s creation of C_2O_4.

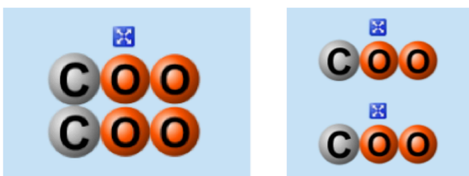
Figure 11: George’s second attempt at C_2O_4 and the separation of this molecule.

George and Jeff’s interaction proceeded as follows:

44:20 (*George drags C-O-O to the $2CO_2$ box, C-O-O is rejected*)
44:23 Jeff: No, cut this one [the right-side O atom] off. (*George cuts the carbon bond, thus leaving C and O-O. He then recombines them into C-O-O.*)
44:27 Jeff: No, cut this one [the O-O bond in C-O-O]. (*George cuts the O-O bond, leaving C-O, and attempts to drag C-O to the $2CO_2$ box)*
44:31 Jeff: No, put this one [the unbounded O atom] *there* [to the left of C in the C-O]
44:35 George: Oooohhhhh! (*builds O-C-O*, *the goal box lights up – indicating a molecule can be collected there. George drags CO_2 into the box.*)
44:44 George: Ooohh. Ok, I get it.

This interaction marked a turning point in George’s interactions with the “Collect Multiple” tab of the simulation. After this interaction with Jeff, he appeared to understand the meaning of the coefficients of molecular formulae. Within 52 seconds, George completed all five of the remaining goal boxes without hesitation.

George’s interaction with the simulation and with Jeff was approximately 8 minutes of productive use of the simulation in this part of the assignment. Heuristic 3 (Set up ***game-like situations*** and take advantage of ***explicit and implicit challenges***) led George to be able to interact with the challenge in the simulation, and this challenge helped to keep him on task so that he could eventually complete the $2CO_2$ goal box. Additionally, Heuristic 2 (Use the simulation to ***mediate discussion***) was present in Jeff and George’s discussion about how to build CO_2. The advantages of Heuristic 1 (Use the simulation to ***coordinate multiple forms of***

representation) can also be seen in the simulation itself, and George eventually had to learn how to coordinate the molecular formula ($2CO_2$) with the pictorial representation of $2CO_2$.

George's interactions with the simulation were similar to other students' interactions during the assignment, and the effects of this can be seen in student performance on pre- and post-tests. The pre-tests and post-tests asked students to draw specific molecules. For most students, their drawings changed dramatically before using the simulation compared to after using the simulation. An example of a pre-test/post-test comparison for a student on one question of the test is shown in Figure 12.

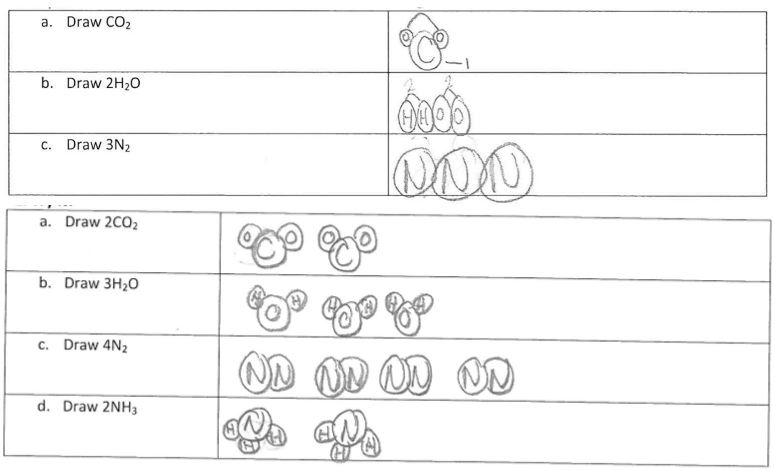

Figure 12: Example *Build a Molecule* activity pre-test (top) and post-test (bottom) results for one student.

Additionally, the overall pre-test/post-test results show high learning gains for students in the class. For example, students were asked to write the chemical formula of $4H_2$ from a picture of the molecule. No students answered correctly on the pre-test, while 63% of students answered correctly on the post-test. For a question asking students to draw $3N_2$ (on the pre-test) and $4N_2$ (on the post-test), 17% of students answered correctly on the pre-test while 78% of students answered correctly on the post-test.

This case study supports the utility of the heuristics in creating assignments to incorporate simulations. The success of this assignment can be interpreted in terms of its alignment with the framework in Section II. The assignment, the simulation, and the environment all worked together to lead to productive student use of the simulation, and this result was clear from the screen capture analysis of productive student interaction with the simulation and the pre-test/post-test comparisons. The heuristics supported this alignment of the different elements of the framework and allowed students to productively use the simulation supported by the assignment.

VII. Conclusion.

This paper presented a framework that highlights the contextual nature of writing assignments for the use of simulations. The goal of the framework is to provide a general picture for how to create assignments that help students productively use simulations. As a part of this framework, a set of heuristics was provided to help educators write assignments appropriate for their students' environments, using simulations.

This work extends technology education research by providing both a framework and a complementary set of heuristics. The framework gives an overall view of the interrelations of different context elements, while the heuristics provide actionable strategies for how to create assignments based on that context. By providing a framework and heuristics, this paper contributes an overarching view of contextual elements and how they interact, as well as actionable strategies for integrating those elements. Here, we summarize these two pieces:

The framework presented in Section II relates the Environment, Assignment, and Simulation to each other and the intended outcome; namely, how students use the simulation. In order to promote productive use of the simulation, these elements should work together to help students engage with the different context elements. Heuristics are provided as strategies for integrating these elements and promoting productive simulation use. The heuristics include: Use the simulation to coordinate multiple representations; use the simulation to mediate discussion; set up game-like situations and take advantage of explicit and implicit challenges; focus on illuminating cases; ask students to re-create or re-present features on the simulation, use "Predict, Observe, Explain" methods.

A case study of quantum tunneling was described to illustrate the need for these heuristics in creating an effective assignment, and problems that arise when assignments are written without the incorporation of these heuristics. A case study of molecule-building illustrated a successful simulation-based assignment, where the heuristics and attention to the broader framework were present in the assignment design. In this instance, we observed productive student use of the simulation, where students engaged in sense-making with the simulation, and utilized other students in the environment to mediate their understanding.

The heuristics utilized in alignment with the framework are not meant to be foolproof laws that will never fail, but instead, should be thought of as highly contextually dependent strategies that can aid in the task of writing assignments. We hope the framework and heuristics presented provide a base on which more research can be done.

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Appendix

Appendix 1. Online Reference Materials.

The assignments used in the studies, the modified tunneling tutorial outline, and the tunneling overview can all be found at: http://spot.colorado.edu/~rehnd/heuristics/ or on the JoTLT website (under Archives, Volume 2, No. 1) at jotlt.indiana.edu.

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Using virtual environments for synchronous online courses

Gregory Steel[1] and Scott L. Jones[2]

Keywords: Online Instruction; Virtual Reality; Second Life

Framework

The dominant paradigm for online instruction focuses on asynchronous activity (where users communicate at different times, such as electronic mail or recorded videos), whether traditional online courses, such as described by Russell and Curtis (2013), or massive online open courses (MOOC), such as described by Rodriguez (2012). However, little research focuses on courses centered on synchronous online education technologies (where users communicate during the same time period). Synchronous communication technologies offer potentially superior options in online education settings compared to asynchronous communication technologies. Media richness theory argues that media offering more non-textual cues and the possibility for immediate feedback are more effective for communication, particularly in situations where ambiguity or confusion are more likely (Daft, Lengel, & Trevino, 1987; Rice, 1992; Schmitz & Fulk, 1991; Trevino, Lengel, & Daft, 1987; and Zmud, Lind, & Young, 1990). As educational environments offer hold potential for ambiguity and confusion, it is likely that course formats offering richer communication could improve learning. Richer media also can increase the presence of an online instructor. Student perception of the social presence of an instructor has been found to be highly influential to the success of online courses (Hodges & Cowan, 2012).

This article describes how teachers can use virtual environments to teach synchronous online classes. Virtual online environments offer a potential tool for supplying rich, synchronous online communication that comes close to mimicking the traditional classroom environment. Virtual environments feature detailed, 3-D settings within which users, represented by avatars, can explore and interact. While many online virtual environments exist, this paper focuses on one such environment—Second Life—as at the time of this writing, it is free and relatively simple to use. The use of Second Life as an example of an online virtual environment should not be construed as a product endorsement.

Second Life is the most studied virtual environment for education. However, while Second Life has been studied as an online learning tool, its use has not been studied within mostly synchronous online courses. Studies have focused on its use as a tool within traditional face-to-face courses (deNoyelles & Seo, 2012; Mayrath, Traphagan, Heikes, & Trivedi, 2011; Sierra, Gutierrez, & Garzon-Castro, 2012; Sutcliffe & Alrayes, 2012), for use in part online, part face-to-face hybrid courses (Hornik & Thornburg, 2010), or for use as an additional activity for traditional online courses (Mansour, Bennett, & Rude-Parkins, 2009).

Combining virtual environments with other Web 2.0 tools can create a largely synchronous format for online interaction that mimics much of the rich interaction of face-to-face instruction without many of the limitations imposed by geography, allowing students anywhere to take the course.

[1] Assistant Professor of Fine Arts and New Media Communication, Indiana University Kokomo, gsteel@iuk.edu
[2] Associate Professor of Fine Arts and New Media Communication, Indiana University Kokomo, scotjone@iuk.edu

Making It Work

There are a variety of requirements and preparations for teaching in virtual environments, including choosing which one to employ. While there are various options available for virtual environments, Second Life was used by the lead author. Owned by Linden labs and started in 2003, Second Life is free to use. To access it, one only needs to visit its website (secondlife.com), create an account, and download and install the viewer software (available for Windows, Mac and Linux operating systems).

Before starting the course, the teacher needs to become familiar with the software to learn how to create an effective course and prepare students. In addition, when entering the course into the university course enrollment system, the instructor needs to make sure the course is clearly described so students understand the nature of the course before they enroll—the virtual environment can surprise students used to traditional online courses, as can the synchronous format. As a synchronous platform, the course needs scheduled days and times to meet. It should also be specified that students need a computer and broadband access, and any other hardware the instructor requires. If audio will be used, computers will need a microphone and speakers or headphones.

The instructor should also talk with campus IT support staff to learn if they will provide help for students. If many of the students in the class live within driving distance of the campus, an optional face-to-face training session before or during the first class period could be helpful, particularly if students have access to computers during the training session, such as in a computer lab or through their own laptops connected to the campus Wi-Fi network.

The instructor also needs to locate virtual locations for students to meet—a variety of public areas suitable for teaching exist, including many created by universities. Instructors can choose spaces ranging from indoor classrooms (Figure 1) to a park by the Eiffel Tower (Figure 2). Users can also pay to create custom spaces. The instructor should also choose a few alternate locations in case the course needs to move during a meeting. To minimize problems during the first class period, it is a good idea to give students practice using the Second Life interface before the initial class, such as a series of introductory tasks to get them to create accounts and acquainted with the virtual environment.

The lead author uses class periods in the virtual environment to conduct discussion of readings, much as one would in a face-to-face classroom. It is important to establish basic rules of classroom etiquette, particularly since many students are new to the environment. The lead author has a rule that only one member of the course at a time has permission to speak using audio. This is because simultaneous speakers using audio can create distortion effects. His students generally interact using text chat windows, thus preventing audio problems. Most students are adept at communicating in this way—given the prevalence of texting in our society, many students are skilled at communicating via brief text messages. The lead author found that this format worked well for discussions; his impression was that some students were more willing to participate in discussions in a virtual environment than in a face-to-face one. Second Life also allows embedded files to be displayed—for example, the instructor could open PowerPoint files and use them as visuals for online lectures and discussions. The rich media environment improved the social presence of both the instructor and of the students, allowing for richer social interaction than many traditional online instruction methods, thus better facilitating relationship building between students and the instructors and students with each other.

Figure 1. **An avatar stands in a space in Second Life modeled on a traditional classroom. There are tables and chairs on tiered levels for the students to sit at and an overhead screen at the front for the instructor's use.**

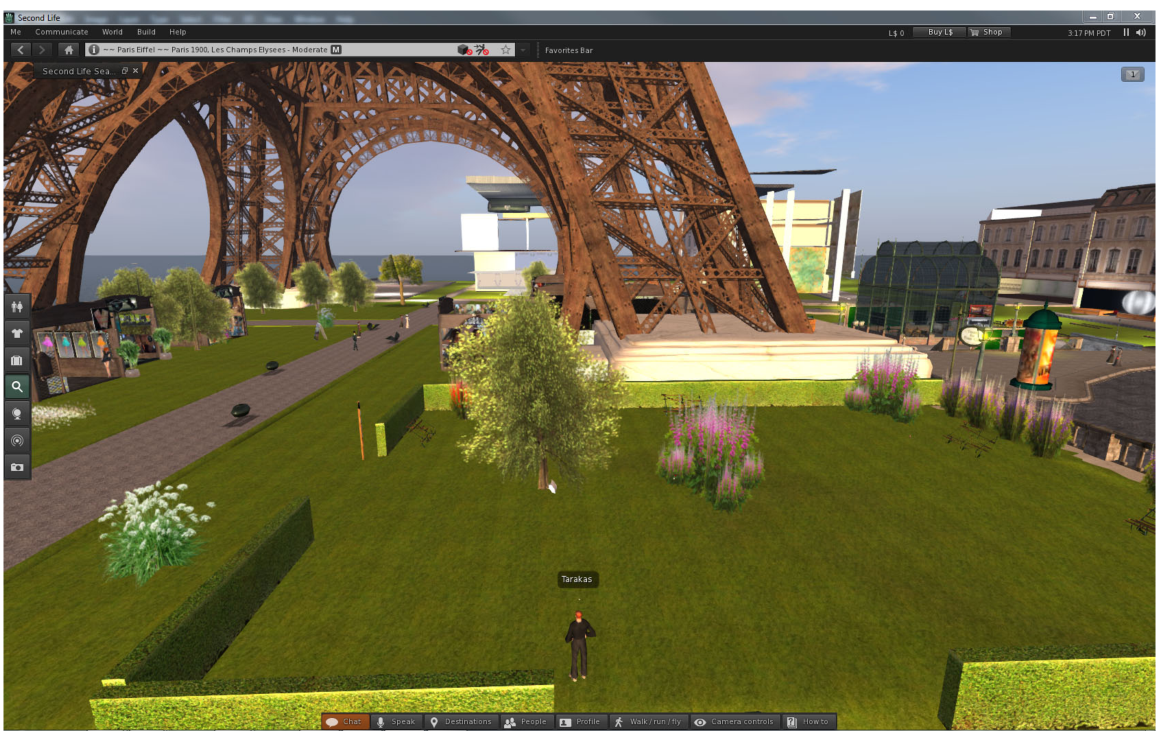

Figure 2. **An avatar stands in a space in Second Life modeled after Paris circa 1900. The avatar is in a park, and the Eiffel tower and buildings are visible in the background.**

There are a few other elements of Second Life instructors need to consider. While many areas of Second Life conform to popular taste, some areas of Second Life contain adult material that might offend some students. One should warn students of this before they start exploring. In addition, anyone can walk into class and begin interacting with students. In some cases this can be disruptive or inappropriate. While one can report inappropriate behavior, this does not immediately eliminate it. It is a good idea, as noted above, for the instructor to prearrange alternate locations for class meetings. In the case of a disruptive visitor, the instructor can tell everyone to teleport (move instantly) to the alternate location. The disruptive user will not know where everyone went and thus will be left behind.

There are other limitations to synchronous online instruction. As the class is vulnerable to technological disruptions, a good backup plan is a must, such as moving the class to a chat room. In addition, students are in front of a computer and may be more tempted to multitask, perhaps by playing games, surfing the Web, watching videos, chatting with friends, etc. In addition, many students participate from home, and during class they can face real world distractions, including unexpected visitors, children, roommates, and pets. This format also prevents students without broadband and suitable computers and hardware from participating, and compared to asynchronous online courses presents less flexibility in scheduling.

While online virtual environments can simulate much of the traditional classroom environment, they benefit by being supplemented by other online tools, such as traditional course management systems, as well as social media such as Facebook, Twitter, and YouTube. In addition, synchronous video communication, such as via Skype or Google+'s video chat feature, can provide additional means of adding a synchronous, social presence to such an online course. The lead author conducts "Skype" office hours and was frequently logged in to many social media channels to communicate with students, thus improving the students' sense of a real person. Furthermore, an instructor can increase connectedness with students by conducting mandatory video conferences—either one-on-one or in small groups. The instructor could do this once during the first few weeks of the semester and could require one or more mandatory follow up conferences during the semester. As the technology changes and becomes more advanced, these strategies can be easily integrated into the digital community and utilized in a seamless way.

Future Implications

Going forward, instructors do not have to forego rich, synchronous interaction when moving from the face-to-face classroom to online instruction; online instructors can use a virtual environment that simulates many of the benefits of the traditional classroom. In addition, instructors can combine the virtual reality synchronous classroom and online asynchronous instruction techniques. Faculty can also use the virtual environment to take classes on virtual "field trips" to virtual recreations of real life places and other environments, thus facilitating learning. For example, students could discuss Roman history or Shakespeare's Julius Caesar while visiting a recreation of ancient Rome. The same Shakespeare students could explore a virtual recreation of the Globe Theatre where Shakespeare's plays were performed. Lastly, instructors can create their own virtual environments to illustrate lessons and facilitate discussion. As the pedagogical discourse continues to evolve and further evidence and questions arise, the flexibility and diverse nature of digital communities with a virtual environment such as

Second Life as the hub will be a viable option and provide a necessary proving ground for the future of higher education.

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Strategies for engagement in online courses: Engaging with the content, instructor, and other students

Beth Dietz-Uhler[1] and Janet E. Hurn[2]

Framework

In recent years, there has been an increasing focus on student engagement (e.g., Pike & Kuh, 2009; Porter, 2009). Student engagement occurs when "students make a psychological investment in learning. They try hard to learn what school offers. "They take pride not simply in earning the formal indicators of success (grades), but in understanding the material and incorporating or internalizing it in their lives" (Newmann, 1992, pp. 2-3). Research (e.g., Kinzie, 2010; Prince, 2004) strongly suggests that when students are engaged, they tend to perform better. When students are actively engaged in the material, they tend to process it more deeply, which leads to successful retention of the material (e.g., Craik & Lockhart, 1972). In this paper, we describe several ways in which online courses can be designed to promote student engagement. All of these techniques are consistent with Quality Matters Rubric Standards (Quality Matters, 2011) area number 5: Learning Interaction and Engagement.

- 5.2 Learning activities provide opportunities for interaction that support active learning.
- 5.3 The instructor's plan for classroom response time and feedback on assignments is clearly stated.
- 5.4 The requirements for student interaction are clearly articulated.

Consistent with Quality Matters, we have used a number of strategies in our course designs to foster student engagement with the course content, with the instructor, and with other students (see Table 1 for a summary of these strategies). Below, we will describe in more detail how these simple course design and implementation strategies can be used to promote student engagement.

Making It Work

Student Engagement with Course Content. To encourage students to engage with the course content, we employ several strategies. In most of our courses, students primarily receive content from a textbook and from videos and interactive activities. One strategy we use is to create short (no more than five minute) audio introductions to each module. These introductions involve the instructor talking enthusiastically through four to five PowerPoint slides and presenting a general overview of the module content. We use Knovio (www.knovio.com), which is free and does not require any software for students to download. Additionally, we require students to complete a number of engaging, online, interactive activities. These activities are generally in the form of a game, which most students find to be stimulating (e.g., Davidson, 2011). Many activities of this sort can readily be found online (e.g., Merlot: www.merlot.org) or through textbook publishers (e.g., Pearson's MyStatLab: www.mystatlab.com).

[1] Beth Dietz-Uhler, Department of Psychology, Miami University, Middletown, OH, 45042; uhlerbd@miamioh.edu, (513-727-3254).
[2] Janet E. Hurn, Coordinator of Regional E-Learning Initiatives, Miami University, Middletown, OH, 45042; hurnje@miamioh.edu, (513-727-3341).

Table 1. ***Summary of Strategies for Student Engagement.***

Engagement with Content	**Engagement with the Instructor**	**Engagement with Other Students**
Listen to the audio introductions	Listen to audio introductions	Respond to classmates' critical thinking answers in discussion board
Engage in the online interactive activities	Watch short, how-to videos	Participate in "Open Discussion" in Learning Management System
Complete mini projects	Read frequent feedback in email and in Learning Management System	Participate in exam review activities
Respond to critical thinking questions in discussion forum	Read "bookend" weekly emails	
	Participate in "Ask the Professor" Discussion in Learning Management System	
	Read and respond to individualized "How's it going?" emails	
	Read and respond to professor's email responses	

Another strategy we use is to require students to complete a "mini project" for each module. The mini projects are designed to require students to apply the material from the text and the interactive activities, relate the material to their own lives, to learn or make use of existing skills such as technology or creative abilities, and to be fun. One example of a mini project includes writing a letter to your grandparents telling them what you will learn in this course, how it applies to your life and to their lives, and what questions you have about the material. When students apply course material to their own lives, they tend to remember the information better (e.g., Roediger, Gallo, & Geraci, 2002). Another example is for students to create a short video (we suggest they use Screenr or Screencast-O-Matic) explaining the parts of the brain and the nervous system. Other mini projects involve creating posters, public-service brochures, and letters to a newspaper editor.

Student Engagement with Instructor. We employ a number of different strategies to encourage interaction with the instructor. In addition to the audio introductions previously described, we also create short, "how-to" videos (using Screenr or Screencast-O-Matic) to present "Frequently Asked Questions" about the course, to show students how to access feedback in the Collaborative Learning Environment (CLE), or to show students how to use software to create a poster. Like the audio introductions, it is important that students know that it is their instructor's voice they are hearing in the audio. Additionally, for each module, students receive feedback from the instructor on their work. Feedback is given in the course CLE as well as via email. The instructor also sends "bookend" emails each week which provide general feedback on the prior module and previews the next module. Typically, the instructor will try to add a sentence or two that is not course-related, such as a comment about a sporting event or the weather. We also engage with students in an "Ask the Professor" discussion board in the course CLE. The idea is for students to ask questions about the course, the material, or anything else. Other students can then see the student's questions as well as the instructor's response.

One of the most important strategies that we use is to send personalized "how's it going?" emails to students two times per semester. The goal of these emails is to let students know that we care about them, which we know is vitally important to student success (e.g., Christophel, 1990; Swan & Richardson, 2003). We estimate that about 90% of students respond to these emails to let us know how the class is going for them and how they are doing in general. Finally, we respond quickly to students' emails to us. We hear often in course evaluations that students appreciated our quick responses as it let them know that the instructor cared about them. All of these strategies are employed to achieve the goal of promoting student engagement.

Student Engagement with Other Students. There are three primary mechanisms we use to encourage student engagement with other students. First, students are required to post a response to two other students' critical thinking answers in the CLE discussion board. Students post these responses for all modules, so they are interacting every week with their classmates. Second, there is an "Open Discussion" board in the CLE, which students (and the instructor) can use to post comments or questions about anything. In general, if students do not initiate discussion, then the instructor will. Topics might include queries about favorite movies or books, requests for comments on current events, or a simple query asking how everyone's weekend was spent. Third, for each exam, students are required to complete some type of review and post to the discussion board. The review might take the form of generating questions about the material, creating a concept map, or writing a few paragraphs about how the material across three modules is connected. The "interaction" takes place with the requirement that other students are required to read what students have posted (and yes, students are told that the CLE records, for the instructor, who reads what post).

Future Implications

We have been employing these engagement strategies in our courses for many years as they are consistent with how we design our courses with Quality Matters in mind. How do we know if our students are engaged? Research (e.g., Johnson, 2012) suggests that students are engaged when they exhibit the following behaviors:

- Paying attention
- Taking notes
- Listening
- Asking questions
- Responding to questions
- Reacting
- Reading critically
- Writing to learn, creating, planning, problem solving, discussing, debating, and asking questions
- Performing/presenting, inquiring, exploring, explaining, evaluating, and experimenting
- Interacting with other students, gesturing and moving

Anecdotal evidence suggests that our students are exhibiting many of these behaviors, leading us to believe that they are engaged with the material, the instructor, and other students. For example, students are frequently interacting with other students in the online discussion board, they seem to take pride in the mini projects for each module, and they typically exceed minimum word counts on projects and critical thinking questions. They also regularly engage via email with the instructor and report that they are enjoying the class and learning.

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Anonymous online student surveys anywhere

Vicky J. Meretsky

Keywords: assessment, CATs, knowledge survey, opinions, student-centered teaching

Framework

Anonymous surveys can be a valuable tool to gather information from students regarding their perceptions of their own learning styles and progress, of an instructor's teaching styles, assignments, tests, and of other aspects of the learning environment. Some course-management software systems provide a built-in capacity to administer an anonymous survey, but not all do, and not all instructors have access to course management software. In addition, students may not always trust the anonymity of one module of a software system whose other modules are explicitly not anonymous.

Free online surveys are available through several providers including (in early 2013) SurveyMonkey, KwikSurveys, QuestionPro, and others. Instructors from anywhere in the world can access the services. Surveys are easy to construct and a survey-specific URL makes them available to students for any desired period of time. Results of multiple-choice questions can be summarized and answers to essay questions can be collected within the software. Survey results can be used to promote reflection by students and instructors, monitor student progress, and fine-tune teaching approaches.

Making it Work

Because instructors have no means to compel students to take anonymous online surveys or confirm that students have taken them, these surveys are best used in a support role, rather than as a required activity. Surveys targeted to assess specific assignments, events, etc., can be time-limited, but surveys could also be used to provide a means of general, anonymous feedback throughout the semester.

Online sites that provide free surveys tend to permit a wide variety of question types, including single-answer multiple choice, multiple-answer multiple choice, essay questions, ranking, ratings, and matrixes. Fixed answers, such as in multiple-choice questions, are easier to summarize, but essay questions permit more thoughtful responses. Templates may be available, with standard questions for various uses, including university instructor evaluations.

I find it very helpful to quickly distribute a short, targeted survey to sample student reactions to a new teaching approach or an activity based on difficult subject. The kind of information I elicit in a targeted survey is different from the on-the-fly, in-class classroom assessment techniques (CATs; Angelo & Cross, 1993) such as asking students to list the most difficult or least clear concept in a given class period. I try to keep targeted surveys short (5-6 questions). I begin with a multiple-choice question or two, such as a Likert scale (strongly disagree, disagree, neutral, agree, strongly agree, don't know) question, because students can answer those quickly, and generally do so. If they choose not to take the time to answer a later essay question, I at least have their answer to the summary question. For an end-of-semester survey to supplement the required survey at my institution, I often use slightly longer (6-10 question) surveys that combine focused (*Was homework feedback sufficiently timely and* *detailed?*) and completely open questions (*Please add any other comments you like*). Instructors who have not previously written survey questions may want to consult some basic reference material on survey design but I find my information needs are usually fairly clear-cut, which simplifies question construction. Anonymous surveys can also be used for pre-post learning assessments as one measure of learning outcomes.

Some sites (e.g., SurveyMonkey, QuestionPro) limit the number of questions or the number of survey respondents in their free services, others (e.g., KwikSurveys) do not. Some providers also have commercial versions with increased support and services, as well as more flexible downloading options. Advanced analyses of survey results require transferring survey results to another platform such as a spreadsheet or statistical package, and free services vary in the ease with which large or complex response sets can be downloaded.

For surveys that may be pilots for larger studies, designers might use the freeware version from a supplier that also offers commercial support; if the pilot study evolves into a larger project, the commercial support may be welcome. Indiana University presently supports discounted prices on several levels of annual Survey Monkey subscriptions for instructors on all its campuses, and other universities may also support such services.

Future Implications

Metacognition – the practice of reflective learning – is encouraged both in students and in instructors (Brookfield, 1995, 2006; Schön, 1987). Anonymous surveys provide us with the means to do both simultaneously: to learn about how our teaching is perceived, while asking to students to reflect on their learning.

I have rarely had all students in a class respond to either targeted or end-of-semester summary surveys, but I generally get answers from well over half my students (graduate and undergraduate, class sizes of 25-50) and from a range of levels of progress and satisfaction. Students often provide thoughtful and well-reasoned critiques that give me an opportunity to consider aspects of the course through the lens of their experiences.

If I receive conflicting responses on a question, I may take the issue back into the classroom to explore it further. Giving students the opportunity to understand that they are not uniform in their responses can help to defuse frustration or stronger emotions. Evidence of diversity in student responses reminds students that the instructor's goal must be to support all class members in their learning and that they, the students, are all part of each other's learning environments. Clickers and other instant-feedback devices could also supply this kind of range-of-reaction information, but they are not in wide use, whereas online surveys are freely available wherever Internet access is available.

As we strive to become more intentional and transparent in our teaching–clearly enumerating desired learning outcomes and linking activities and assignments to those outcomes–quick, anonymous online surveys are a useful source of evidence to support teaching decisions. In contrast to quick classroom assessment techniques, anonymous online surveys are well suited to address aspects of a course beyond basic comprehension of content. They give students more time for thought, but still can provide instructors with student feedback in a time-frame of days: much closer to the same-day or same-week response of classroom assessment techniques than the after-the-semester response of institutional course evaluations. To give closure to students, instructors should, in turn, give students feedback on what they learned from surveys and how or whether they will act on information (Angelo & Cross, 1993). Closing the loop with students is easier to do with surveys that are taken during the course when conversation with students is still straightforward, but instructors may be able to provide feedback on end-of-course survey results by email, if desired.

Online survey results are a good way to demonstrate reflective teaching and teaching that promotes reflective learning. Results of these quick, shorter surveys can be used in teaching portfolios and can be a foundation or stepping-stone for scholarship of teaching and learning. Anonymous online surveys are quick to create, easy to administer, and easy to archive. They produce useful results that can promote better, evidence-informed teaching and better learning.

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Does contiguous effect matter in PowerPoint presentations for effective instruction?

Ju Park[1]

Keywords: teaching practice, presentation delivery, contiguity, cognitive overloading

Framework

Generally, prior to instruction, instructors need to determine what kinds of materials and what types of presentation media would be most appropriate for delivering instructional content to students (Oliver & McLoughlin, 2001). Typically, when utilizing electronic media, instructors have a variety of options to choose from, such as web sites, computer software programs, instructional videos, and multimedia presentations (Bitter & Legacy, 2008).

Multimedia is "a computer-based product that enhances the communication of information by combining two or more of the following elements: text, graphic art, sound, animation, video or interactivity" (Ellis, 2001, p. 110). In addition, the effective use of multimedia software by both instructors and students has been dependent on capability of the features to present textual, visual, and auditory information (Alkazemi, 2003).

In regard to effective use of visuals in a multimedia presentation, a number of studies have examined the effectiveness of visuals used in various instructional tasks (Bitter & Legacy, 2008; Demirbilek, 2004; Hack, 2004). Although studies have found positive learning outcomes in use of both still and moving pictures in their experiments, other studies contrastingly found that visual aids such as graphics and pictures in electronic instructional materials may have either no effect or a negative impact on students' learning outcomes, dependent on how electronic instructional materials are presented to students. In light of the possibility of negative impact, studies (Martin-Michiellot & Mendelsohn, 2000; Schuler, Scheiter, Rummer, & Gerjets, 2012) demonstrated that the use of animation with text was not consistently effective for students' perception, in terms of information processing. These studies stated that a possible reason for this lack of effectiveness was related to a presentation variable identified as contiguity.

Making It Work

Contiguity in Electronic Presentation. Contiguity refers to successive, rather than simultaneous, presentation of visual and textual information. If text, animation, and other forms of visual aids are successively presented on electronic media such as PowerPoint by presenters, a presentation can be regarded as a contiguous presentation, rather than a simultaneous presentation (see Table 1). In terms of contiguity, researchers (Johnson & Mayer, 2012; Mayer & Moreno, 2002) argue that (a) whether or not animation has a positive impact may be partially dependent upon spatial contiguity effect and (b) students' learning outcomes such as comprehension and short-term recall may be affected by not only content materials, but also the presentation itself. Consequently, it implies that among electronic learning materials, an electronic presentation integrated with animation and on-screen text may not produce a positive impact on students learning, if not contiguously presented (Johnson & Mayer, 2012; Mayer and

[1] Assistant Professor of Education, Indiana University Northwest, park49@iun.edu

Moreno, 2003). In addition, it is recommended for instructors to understand the effect of contiguity, when delivering content information in a multimedia presentation, because student learning seems to be affected by not only the content of textual and visual information, but also how it is presented (Lin, 2006; Shaw, 2003). Thus, it may be valuable for instructors to understand how contiguous usage of textual and visual information effectively works in electronic presentations such as PowerPoint.

Demirbilek (2004) states that the recall capacity of students in an electronic learning environment may be decreased, due to the occurrence of cognitive overloading generated by too much information presented simultaneously. Also, his study demonstrates that simultaneous input of both textual and visual information is more likely to result in cognitive overload rather than simultaneous input of textual information only. According to the study by Mayer and Moreno (2003), when students receive various visual information (pictures, graphics, animation, and other types of visual stimuli) at the same time, they may experience ineffective learning, because they are required to simultaneously execute different information processes. Accordingly, given with possible occurrence of cognitive overloading, inappropriate simultaneous display of information on each PowerPoint slide may be more likely to generate learning hindrance by too much information process per learning activity rather than contiguous display.

Table 1. Types of Information Display on Presentation Slides.

Simultaneous Display of Textual Info	**Air** **Blue Sky** **Hot Weather**		
	Slide 1		
Contiguous Display of Textual Info: Type A	**Air**	**Air** **Blue Sky**	**Air** **Blue Sky** **Hot Weather**
	Slide 1	Slide 2	Slide 3
Contiguous Display of Textual Info: Type B	**Air**	**Air** **Blue Sky**	**Air** **Blue Sky** **Hot Weather**
	Slide 1	Slide 1	Slide 1

Future Implications

Effective Display of Information in PowerPoint. As previous research has shown that cognitive overload is a major problem in electronic learning (Demirbilek, 2004; Hack, 2004), it suggests that the contiguous display of animated graphics with text might attenuate cognitive overloading (Mayer & Moreno, 2003; Paas, Renkl, & Sweller, 2003). As resulted in the previous research, instructors should incorporate more contiguous, rather than simultaneous, displays of textual and visual information they produce, in using electronic presentations such as PowerPoint.

Moreover, because the previous research has focused more on visual modality, as opposed to multiple-modalities (visual and auditory), different results could be found if the experimental materials had been designed, based upon multiple-modalities. Thus, a future study may consider multiple-modalities. Specifically, if an experiment uses both visual and auditory modalities, results may be dissimilar to the current results because student learning is also impacted by auditory information (Mayer & Moreno, 2002; 2003). In addition, the previous studies (Grace-Martin, 2001; Rummer, Schweppe, Fü rstenberg, Scheiter, & Zindler, 2011) indicate that the material designed based upon multiple-modalities may create more cognitive load rather than the material designed based upon a single-modality.

Therefore, although contiguous display of information on PowerPoint slides may not always generate positive impact on student learning, contiguous display of textual and visual information on PowerPoint slides is recommended, expecting that simultaneous display generates cognitive overloading, based on the studies conducted. Since instructors and college students, nowadays, utilize more electronic learning materials in face-to-face, hybrid, and online learning environments (O'Bannon & Puckett, 2010), proper visual displays of instructional contents in presentation materials may be critical both for instructors to deliver contents effectively and for students to process contents cognitively successful.

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Digital discourses: Implementing technology within the public speaking classroom

Andrea M. Davis[1] and Desiree D. Rowe[2]

Keywords: public speaking, digital citizenship, podcasting, digital storytelling

Framework

In this semester-long project, students will be able to utilize various digital tools to meet four outcomes within the Public Speaking classroom. First, we are focused on the student's ability to demonstrate critical consumption of media technologies. Second, students should use these technologies to narrate and curate current events. Third, technology should not hinder collaboration; rather we are seeking to utilize technology to encourage collaborative efforts that may have been impossible prior to the implementation of the technology. Finally, we place an emphasis on the student's investment in digital citizenship.

For this project we place an emphasis on the notion of participatory culture, where individuals are part of a larger sustained cultural project that creates and facilitates (rather than just observes) the cultural production of information. In the classroom, our emphasis on participatory culture is manifested in our use of technology in relation to public speaking. We insist that students critically engage their own experiences and reaction to others experiences both creatively and digitally. Prior to our emphasis on technology, we felt that the public speaking classroom existed in a vacuum, where the ideas expressed barely heard by other students and were rarely engaged in relation to the outside world. Considering our location in the southeastern United States and over an hour from a large metropolitan city, we turned to technology in order for students to engage on a larger, more participatory scale. Finally, this project also de-emphasizes the traditional public speaking ethos of Truth. Rather, we encourage students to work together to push the boundaries of thinking about topics and ideas, relying on their own experiences as meaning-making.

Making It Work

This project was developed though our faculty development institute's technology initiative. We were asked to redesign general education courses with a technology-intensive focus. In redesigning the public speaking course, we incorporated tools students already used as well as new tools to reinvent the traditional three speech model of public speaking. We asked students to do a digital story, podcasting, and blogging, in addition to a traditional persuasive speech. Leaving the traditional speech within the curriculum was a purposeful choice, one made to allow students to compare different communicative experiences and still get a "traditional" public speaking experience. To ease collaboration and communication across the course projects, some

[1] Assistant Professor of Communication Studies, Department of Fine Arts and Communication Studies, University of South Carolina Upstate, amdavis2@uscupstate.edu
[2] Assistant Professor of Communication Studies, Department of Fine Arts and Communication Studies, University of South Carolina Upstate, drowe@uscupstate.edu

students used Twitter outside of class to ask questions of the instructor and other students; this was not mandatory and not all students participated.

Phase 1. A digital story replaced the traditional introductory speech assignment. Leopold's (2010) assignment on media stories for persuasion was adapted to fit the needs of an introductory assignment. Using Microsoft PhotoStory and/or iMovie students were asked to design a digital story that would introduce themselves to the class. I placed particular emphasis on not merely hearing about the photographs, but encouraged students to reflexively engage the photos in order to make a coherent narrative. Further, this project emphasized audience analysis, asking students what narrative they wished to share with their classmates.

We had a one 75 minute class period workshop with PhotoStory where students learned the basic functions – how to add photographs, arrange them, and add music/voiceover. Homework included completing additional tutorials on the program. We then had a question and answer day the following week to deal with issues regarding both the assignment and the software. From that point, I worked with students on an as-needed basis on the project. Most students requested additional help with editing, including adding effects, to the recording.

After creating a two to three minute digital story, we had a presentation day where students introduced their digital story and then played it for the class. In creating the story the students were required to consider their audience's needs as well as prior knowledge. They had to consider the effects of the visual (their photos) and audio (music/voice) choices in crafting a message. Students were evaluated on content (45%), including clear narrative, the significance of the narratives and the photos used and delivery (45%). Effective use of PhotoStory/iMovie software, as determined by their visual/audio product, was 10% of the assignment grade.

*Phase 2***.** Most semesters I ask students to critique an outside presentation. In the public speaking classroom, this allows students to apply the knowledge they have learned to produce their own speeches to other, perhaps more experienced, orators in the public eye. In election semesters, I instead ask students to write a critique of one of the debates. To enhance the students' critical consumption of media through their own political discourse, I also created a course blog. I divided the class into two groups. I asked one group to blog the second debate and the second group to blog the third debate. The goal was to get the students to apply course concepts, but with the awareness of a public audience and political discourse. The difference between the blog and traditional assignment is its public nature. Students were required to respond to statements publicly, support their answer to a group, and be aware of the effect their message had on the larger conversation.

I asked the group that was not blogging for a given debate to read and respond to the posts of the bloggers. Questions I posed to the students for the blog included:

- Who is the audience for this debate?
- Did one candidate "win" the debate? Who? Why do you think so?
- What was the most effective message you heard in the debate?
- What did the nonverbal communication of each candidate convey?
- Was your opinion on any of the issues changed through the debate?

Students' posts focused on argument, delivery, nonverbal communication, and debate content. The responses to the posts asked questions (about communication styles/preferences as well as politics) and provided counter-narratives to the original post. Some posts ended up being very lively with over half the class adding into the discussion. This assignment carried over into class (and pre-class) discussions about what candidates could do to be more appealing to likely voters.

While an in-class discussion alone would have helped achieve our goal of dialogic engagement, the blogging component adding another layer of meaning. In our experience, the students who were more reticent to engage the in-class conversation where vocal in the blog posts. This allowed for a more substantive discussion both in-person and face-to-face.

Phase 3. Podcasting replaced the informative speech in order to offer students a chance to "play" with a different type of technology and further explore ways to communicate an informative message. Students created a 4- minute informative podcast on an issue or topic of interest to them. This was a research-based assignment so they were required to use a minimum of five sources for the presentation. After introducing the assignment, I introduced Audacity and showed them a tutorial, which included the basic functions. Their homework was to download Audacity, record one minute of audio, and edit that audio in some way. I also asked them to watch/listen to at least two additional tutorials. From that point, we worked individually and in groups on the podcasts. We had one individual work day where students brought in their laptops and we listened to works in progress and dealt with issues on a case-by-case basis. Students problem-solved together and taught one another about the different editing tools they had learned.

The podcasts were particularly helpful because students saw podcasting as useful to many courses they would take and mentioned how useful they would be in their future careers. Students were evaluated on a revised informative speaking rubric. I tried to keep much of the grading criteria the same as an informative speech, as our goal is to incorporate technology while still maintaining the course objectives. In addition to using the podcasting software effectively for 10% of the grade (though recording, using at least two editing tools, and finalizing the podcast), students were graded on a clear argument, appropriate use of sources, delivery and outline.

Future Implications

The greatest challenge was overcoming students perceived difficulties learning new technology. For example, they were concerned that because they had never done podcasting that they could not do podcasting. As the semester progressed, and they learned each skill set, their confidence grew. In some cases they saw ready-made applications for the tools (i.e. podcasting) and **in** other cases (blogging) we had to discuss ways it could be applied in their work. Students were decidedly more enthusiastic and driven after we discussed, and they saw, the practical application of all of the tools and the relationship to public speaking.

The beginning of the semester was the most challenging; not all the students had bought in to the process and I had some technology difficulties in class that slowed the buy-in. While additional practice and preparation are always helpful, I found acknowledging that moments of difficulty are to be expected was useful. It should be noted that students didn't self-select into this section and so were expecting a traditional public speaking experience. In the future, our university is looking to correct this by marking specific course sections as "technology intensive."

Appendix

Appendix 1. Suggested Readings.

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Book Review

The Online Teaching Survival Guide: Simple and Practical Pedagogical Tips

Shradha Kanwar[1]

Citation: Boettcher, J.V., & Conrad, R.-M. (2010). *The Online Teaching Survival Guide: Simple and Practical Pedagogical Tips.* Jossey-Bass, A Wiley Imprint(pbk).

Publisher's Description: *The Online Teaching Survival Guide* provides an overview of theory-based techniques for online teaching or for a technology-enhanced course, including course management, social presence, community building, and debriefing. Based on traditional pedagogical theory, this resource integrates the latest research in cognitive processing and learning outcomes. From a practical approach, this guidebook presents instructional strategies in a four-phase timeline, suitable for any online or blended course. Faculty with little knowledge of educational theory and those well-versed in pedagogy will find this book a key to developing their practical online teaching skills.

The advent of digital classrooms and online learning has transformed the educational ecosphere. The exponential growth in information has augmented the importance of technology in classrooms. Teachers across the globe are experiencing this driving force and are exploring diverse ways of harnessing the potential of online teaching.

The book brilliantly deals with this most fascinating yet challenging issue of online learning, and gives an orientation to its various facets. Rightly presented as a survival guide with simple and practical pedagogical tips for online teaching, the book showcases an array of strategies to structure an online course, design the pedagogy and also formulate an assessment plan.

The book reinforces the significance of pedagogical theories in establishing the framework on which online teaching practices are orchestrated. "Innovative communication technologies often drive pedagogical change," and the book highlights this transit from face-to-face instruction to online.

The pedagogical practices for online teaching are useful to learners with different learning styles and ability levels. As mentioned by the authors, "Tips comprising the heart of this book were crafted to meet the needs of actual faculty from veteran classroom instructors to novice teachers." The suggestions could be incorporated in fortifying one's own teaching practice or to support the extended academic community.

The book noticeably demonstrates its intent as a forerunner of active and ongoing support for online faculty to ensure an effective and efficient teaching- learning experience. The authors highlight the challenges faced because of the exponential growth in information and the blistering speed at which the environment is becoming technologically immersive.

[1] Area Director, Educational Technology, at NIIT University, shradha.kanwar@gmail.com

A primary theme of the text is that an effective teacher will be equally effective in all formats of teaching, be it face-to-face or online, but this evolution is neither mechanical nor sudden. Therefore, an orientation to the process of online teaching and to the content is critical.

The first chapter of the book gives a holistic perspective on the macro picture of learning and effectively illustrates the distinction between a face-to-face and an online course plan. It also sets the context for the subsequent chapters. The chapter is focused on creating and continuously improving online courses and there is a constant emphasis on the unique style and orientation needed for an online course plan. The component dealing with "How are online courses unique?" sets the foundation for various facets of online teaching, which stand out as very important references for constructing the course. The authors illustrate a variety of inputs on the importance of a real-time learning environment to create well-designed asynchronous interactions, thus leading to improvement of the teaching-learning experience. Further, the uniqueness of the online course plan exemplifies the role of a learner in the process as being more dynamic and purposeful and conspicuously engaged in the creation of knowledge.

Chapter two of the book is structured around the theoretical foundations of pedagogy and its significance for practitioners. It appropriately draws attention to the evolving educational scenario where traditional teaching practices no longer suffice the purpose of meeting learning objectives. The authors introduce the readers to ten core learning principles – the foundation on which the online course plan is designed. These core principles act as guidelines in designing and managing the online teaching environment. They reinforce the role of faculty as mentors, directing the learning experience with emphasis on learning processes to ensure the different learning outcomes. The insights from this section of the book reiterate the role of a learner as the pivot point around which all processes are activated. It significantly points out the aspect of varied experiences accumulated over a period of time and resulting in new learning. The context around which the learning event takes place is critical and there is an adequate emphasis on the advantages of the dynamic digital learning space to ensure richness of perspective and effective learning outcomes. The theoretical foundations expounded in the book act as important references to develop metacognitive abilities. The authors constantly reinforce the need to develop high order thinking skills of deep understanding and lifelong learning, so noteworthy in today's learning context.

Chapter 3 begins with familiarizing the readers with the practical aspect of online teaching. It draws attention to the importance of preparation, presence, and participation in both the synchronous and asynchronous scenario. The best practices highlighted in this section provide an end-to-end course-plan structure, putting emphasis on customized and personalized learning.

The second part of the book, comprising eight chapters, extends the discussion on useful strategies for online teaching. From setting the right foot forward in course beginnings, through an appropriate selection of tools, to avant-garde pedagogical suggestions, to essential course pieces, and defining quality standards, the discussion leads to interesting cognitive revelations around the "zone of proximal development." Additional precepts are shared to hone the talent of interested faculty members with focus on framing the right kind of questions, rubrics for evaluation, discussion forums, and posting to create an immersive learning experience. The tips provide immediate and relevant references to create a stimulating course and handle intensive engagements.

The themes and tools projected by the authors are useful in developing good practices for learning. These practices act as useful guidelines in ensuring engagement and progress of learners. It critically examines the array of offerings in the digital space and emphasizes the importance of right tool selection based on the requirement of the learners. The ultimate goal of any teaching process is to ensure meaningful learning and stimulate intellectual curiosity of the students; this book characterizes this very aspect of learning. Another important aspect of technology customization that is brought out in the book is the necessity of a learner-centric knowledge management system (CMS). According to the authors, the CMS should support deep learning processes and promote collaborative learning experiences. Community building to improve teaching processes is also a focus area where the authors share best practices for online course design and delivery.

Interesting and readily available tools are shared for the benefit of online teachers. These include simple tools for collaboration and communication as well as more refined applications. The authors continuously advocate the need to reinforce the cognitive presence in the classroom through intelligently crafted discussion sessions and projects. Peer collaboration is strongly encouraged through conversations and assessment interventions. Self- development of teachers is an area where the tips induce reflective practices and a sense of accountability amongst teachers. The progression of the chapters is done in a very coherent manner and the reader surfaces with new ideas with every chapter.

Phase 3 of the book focuses on leveraging the power of questions and inculcating inquiry as a reflective practice. These are indeed essential prerequisites for today's millennial generation who are so used to obtaining responses to their queries through a simple Google search. The authors insist on the new and emerging role of the teachers in linking students' new information and concepts with previous knowledge through the art of questioning. As the authors take us to the tips for the" late middle," the emphasis now shifts to integrating knowledge in anticipating and solving problems. Feedback is an important indicator to take stock of the course objectives and to understand the progression of the course to realign it with the learners' knowledge. Tips on feedback strategies that deal with the prospect of improving learning outcomes are illustrated effectively. The suggestions on creating a feedback mechanism that is personal, formative, timely, and efficient are very pragmatic.

Concept mapping for authentic problem solving, collaborative project discussions, and tips to conduct them are hugely relevant in today's learning space, where team building and synergy are the key success differentiators. The book delineates the need to energize learners and maintain a flow to ensure that students are neither underwhelmed nor intimidated in mapping the content. Social networking sites, which are more common as personal interaction forums, are presented in the book as useful cognitive tools in co-constructing knowledge and building a learning community.

Phase 4 of the book gives the modus operandi to embellish and present the neatly designed final product and is directed toward making a learner independent and self-initiated. Finally, the book explores future problem areas that might interfere with the smooth conduct of the course.

Suggestions pertaining to other formats of online learning like mobile platforms, could have added further value to the practical advice section. Some inputs on technology as a liberating mechanism for learners could be added in further editions. The book is a useful reference for teachers who are beginning their online teaching journey. It is equally useful for teachers who have attained a certain degree of proficiency in this area. The challenge of teaching in an unfamiliar territory is gradually erased and replaced with excitement about designing the course plan. The uniqueness with which the book focuses on leveraging technology to provide differentiated instruction in creating an inimitable learning experience is noteworthy.

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Mission

The Journal of Teaching and Learning with Technology (JoTLT) is an international journal dedicated to exploring efforts to enhance student learning in higher education through the use of technology. The goal of this journal is to provide a platform for academicians all over the world to promote, share, and discuss what does and does not work when using technology in postsecondary instruction. Over the last few decades, faculty have progressively added more and more sophisticated technology into their courses. Today, the variety of technology and the creative ways in which technology is being used is simply astonishing, whether in-class, online, or in a blended format. In the final analysis, however, it isn't whether our students - or faculty members - like the technology that matters but whether the addition of these technological tools results in or expands access to quality student learning. JoTLT will play a prominent role in helping higher education professionals better understand and answer these questions.

We will accept four types of manuscripts:

Quick Hits: A Quick Hit is a brief contribution describing innovative procedures, courses, or materials involving technology (1500 words or less). Each contribution should include sufficient detail to allow another educator to use the Quick Hit in his or her own course.

Empirical Manuscript: Manuscripts in this category should provide qualitative or quantitative evidence demonstrating the effectiveness of the technology in increasing student learning. Each manuscript should include sufficient detail to allow another educator to use the technology in his or her own course.

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- Empirical Manuscript: Manuscripts in this category should provide qualitative or quantitative evidence demonstrating the effectiveness of the technology in increasing student learning. Each manuscript should include sufficient detail to allow another educator to use the technology in his or her own course.

- Book Reviews: Book Reviews can be submitted for recently published works related to teaching and learning with technology. These manuscripts are typically less than 1500 words in addition to the complete citation of the book and the publisher's description of the book.

- Case Studies: These studies illustrate the use of technology in regards to teaching and learning of higher education students, usually generalizable to a wide and multidisciplinary audience.

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Editorial Board

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Style Sheet for the *Journal of Teaching and Learning with Technology*

John Dewey[1] and Marie Curie[2]

Abstract: This paper provides the style sheet for the Journal of Teaching and Learning with Technology. Manuscripts submitted for publication should adhere to these guidelines.

Keywords: clickers, iPad, tablet, retention, engagement.

I. General Guidelines for the Manuscript.

The final manuscript should be prepared in 12-point, Times New Roman, and single-spaced. Submissions being reviewed should be double-spaced. All margins should be 1 inch. The text should be fully left- and right-justified. The title (in 16 point bold) and author's name (in 12 pt. bold) should be at the top of the first page. The author's name should be followed by a footnote reference that provides the author's institutional affiliation and address. The abstract should be indented 0.5" left and right from the margins, and should be in italics.

Except the first paragraph in a section subsequent paragraphs should have a 0.5" first line indent. Use only one space after the period of a sentence (word processors automatically adjust for the additional character spacing between sentences). The keywords should be formatted identically to the abstract with one line space between the abstract and the keywords. Authors should use keywords that are helpful in the description of their articles. Common words found in the journal name or their title article are not helpful.

Pages should be unnumbered since they will be entered by the Journal editorial staff. We will also insert a header on the first page of the article, as above.

References should be incorporated in the text as authors name and date of publication (Coffin, 1993), with a reference section at the end of the manuscript (see below for the desired format for the references). Titles of articles should be included in the references in sentence case. Unless instructed otherwise in this Style Sheet, please use APA style formatting. Footnotes should incorporate material that is relevant, but not in the main text.

A. Plagiarism.

It is essential that authors refrain from plagiarism. Plagiarism is a violation of ethics and, in serious cases, will lead to a manuscript being rejected by this journal. No future manuscripts will be accepted from authors who have submitted a plagiarized manuscript.

B. Unique work.

This journal does not accept previously published work. We also do not accept work that is being considered for publication by another journal. If your manuscript is accepted, you will be required to sign a form stating that your manuscript has not been previously published.

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[1]Department of Educational Philosophy, Indiana University Northwest, 3400 Broadway, Gary, IN 46408, jdewey@iun.edu.
[2]Institut Pasteur, University of Paris, 75015 Paris, France.

II. Section and Sub-Section Headings.

A. Major Sections.

Major section headings should be flush-left, bold-faced, and Roman numeral numbered. Major section headings should have one-line space before and after. The first paragraph(s) of the article do not require a major heading.

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Sub-section headings should also be flush-left, in italics, and alphabetically numbered. Sub-section headings should have a one-line space before and after. Sub-sub-sections should appear at the beginning of a paragraph (i.e., with an 0.5" indent, followed immediately by the text of the sub-sub-section), with the heading also in italics.

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Tables and figures should be inserted in the text where the author believes they best fit. They may be moved around a little to better correspond to the space requirements of the Journal. If necessary, tables and figures may occupy an entire page to ensure readability and may be in either portrait or landscape orientation. Insofar as possible, tables should fit onto a single page. All tables and figures should be germane to the paper. Tables should be labeled as follows with the title at the beginning (in bold), with data entries single-spaced, and numbered. Column labels should be half-line spacing above data.

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Pica	1/6

Figures should have their captions follow the image. Captions should be single-spaced, with title in bold. Additional text should not be in bold. The Editorial staff may adjust layout to allow optimal use of space.

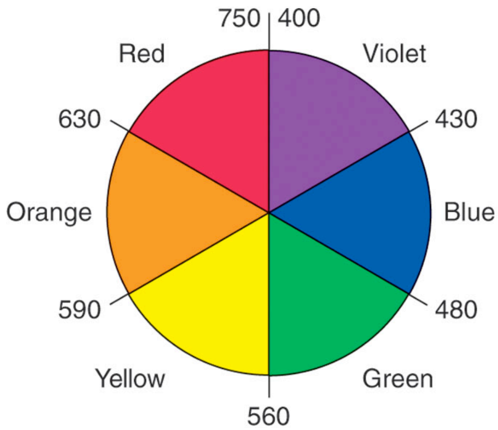

Figure 1. Color wheel with wavelengths indicated in millimicrons. Opposite colors are complementary.

Acknowledgements

Acknowledgements should identify grants or other financial support for this research by agency (source) and number (if appropriate). You may also acknowledge colleagues that have played a significant role in this research.

Appendix

Please insert any appendices after the acknowledgments. They should be labeled as follows:

Appendix 1. The Title of the Appendix.

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JoTLT Editorial Office

Indiana University Purdue University Indianapolis
755 W. Michigan St, UL 1180D
Indianapolis, IN 46202

jotlt@iu.edu

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