



## **Introduction of Reusable Learning Objects in a First Year Materials Science and Engineering Course**

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# **Introduction of Reusable Learning Objects in a First Year Materials Science and Engineering Course**

## **Abstract**

Reusable learning objects (RLOs) were introduced into the introductory materials engineering course for first year students at the University of Toronto. These RLOs were specifically designed to address the topic of fracture mechanics, including fracture toughness and stress concentration. The RLOs included: 1. Online “Khan Academy Style videos (KSV)”, 2. Example problem videos by graduate students, 3. Cornell notes, note-taking framework handouts, 4. Tempered glass lecture demonstration, 5. Online homework problems, and 6. New in-class slides for lectures. At the end of the first semester following the introduction of these new interventions, students were asked to participate in a survey to gauge the rate of intervention uptake as well as general perceived usefulness (n=118). The KSVs had the greatest uptake rate, with 63% of respondents reporting that they used the intervention. The Cornell notes had the lowest uptake rate (4%). When asked about perceived usefulness of interventions, 84% of students agreed that the tempered glass demonstration and new fracture lecture slides were most useful to their learning.

Two focus groups (n=8; 4 students per group) were conducted at the end of the Fall 2013 semester in order to better uncover learning barriers/benefits of the RLOs and gather supplementary qualitative data on the interventions. Students expressed that live demonstrations (tempered glass demonstration) were both engaging and better for concept retention. They did not find the Cornell notes to be useful, but instead preferred to take their own notes freehand. This data corroborated the survey results.

The research team hypothesized that with the uptake of these interventions, student performance on exam questions related to fracture mechanics would improve in comparison to previous years. Data from seven semesters prior to the introduction of the six interventions was collected and compared to the Fall 2013 and Winter 2014 semesters. An average of two fracture questions was posed each semester. Data showed that there was no significant difference in student performance on fracture exam questions following the introduction of the RLOs.

These results show that there is room in introductory materials engineering courses for innovative tools such as reusable learning objects to better address different learning styles. Based on these survey and focus group responses, further adjustments will be made to the curriculum to better meet student expectations and needs.

## **Introduction**

More university level courses are emphasizing concepts with the help of technology, thus better targeting student “culture”; these are often referred to as next generation learning environments (NGLE) <sup>[1,2]</sup>. Use of screen-capturing and other video capturing software is becoming the norm in higher education for supplementing traditional lectures <sup>[3-5]</sup>. Engineering programs have become vanguards in this adoption; as engineering courses are both content-rich and move at a fast pace, there is a place for supplemental material to better emphasize difficult concepts <sup>[6]</sup>. A number of these materials now focus on the learner-interface interaction (e.g., student and computer interface), which is a type of interaction gaining momentum; especially with the rise of Massive open online courses (MOOC) <sup>[7, 8]</sup>.

The University of Toronto Engineering faculty accepts over 1000 students per year. An introductory materials science course is mandatory for all first-year engineering students at the University of Toronto in Toronto, Canada. Approximately 240 students are enrolled per semester in one of these introductory courses (MSE101), separated into four sections, and taught by one instructor. Each section meets with the instructor three times a week for an hour. A one-hour tutorial is also run once a week; each tutorial group is made up of between 35 and 45 students and run by a graduate student. In order to better address different learning styles of this diverse group of students, six reusable learning objects (RLOs) were introduced into the fracture mechanics module/chapter of the course in Fall 2013. The RLOs included: 1. Online “Khan Academy Style videos (KSV)”, 2. Example problem videos by graduate students, 3. Cornell notes, note taking framework handouts, 4. Tempered glass lecture demonstration, 5. Online homework problems and 6. New in-class slides for lectures.

The objectives for this study were to disseminate the RLOs and to evaluate their efficacy. The efficacy of the RLOs was evaluated two ways. First, students were surveyed at the end of the

academic semester to gather perceptions of usefulness of the RLOs. Second, course grades were analyzed in order to see whether academic performance improved with the use of RLOs.

## Method

### 1. Intervention Design

#### *a. Online KSV*

Online KSV (Khan Academy Style Video) follow their namesake's format. The course instructor's voice is simultaneously recorded with a tablet screen that shows his writing as he explains a concept on the topic of fracture that is commonly misunderstood or found to be challenging to students. Diagrams as well as any applicable formulas were drawn to complement the real-time explanation. This format was tested by Kawano, et.al<sup>[6]</sup>. Kawano surveyed students to gather whether explanatory narration affected student learning in a supplemental video. According to the results, almost all the students (56 of 58 students; 97%) agreed that some level of narration is important to them, while 71% of students rated narration as being "very important" (Figure 1)<sup>[6]</sup>.

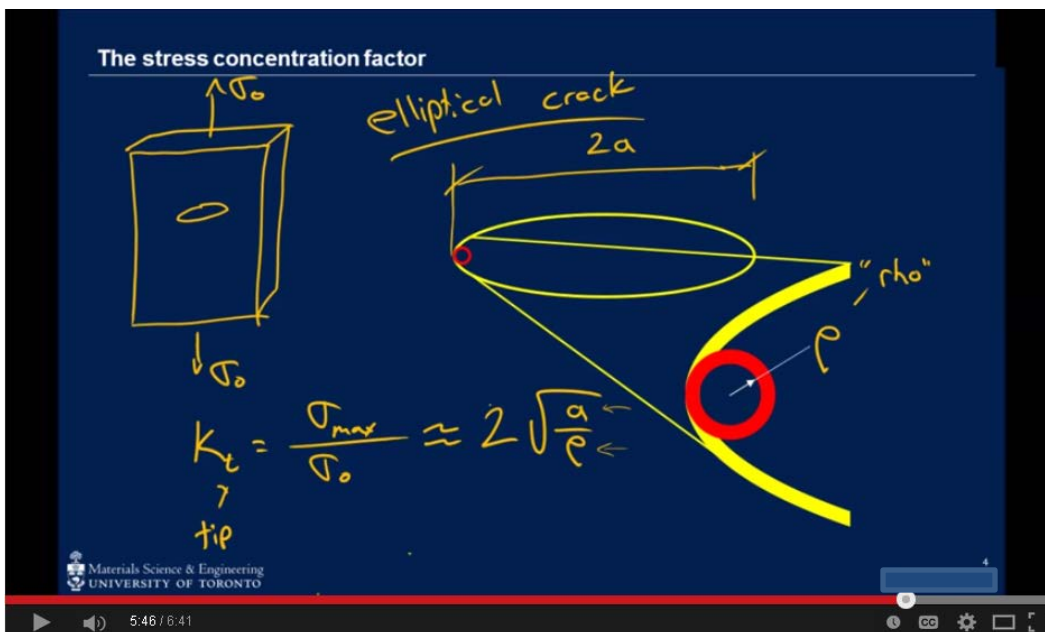


Figure 1: Still image of Online KSV explaining fracture concept of stress concentration; video is narrated by course instructor and posted on instructor's YouTube channel for students to view

*b. Example problem videos by graduate students*

A materials engineering graduate student was hired to create two videos in which he solved an example problem related to plane strain fracture toughness and another related to approximating the stress concentration factor at the tip of a crack. The videos depicted the graduate student working on the chalkboard, so that students could follow along with the solution in real time rather than watching the student explain a completed solution. Furthermore, the videos were kept brief (4.5 and 6.5 minutes), based on the rule-of-thumb that shorter videos will keep students more engaged (Figure 2) <sup>[6, 9]</sup>.

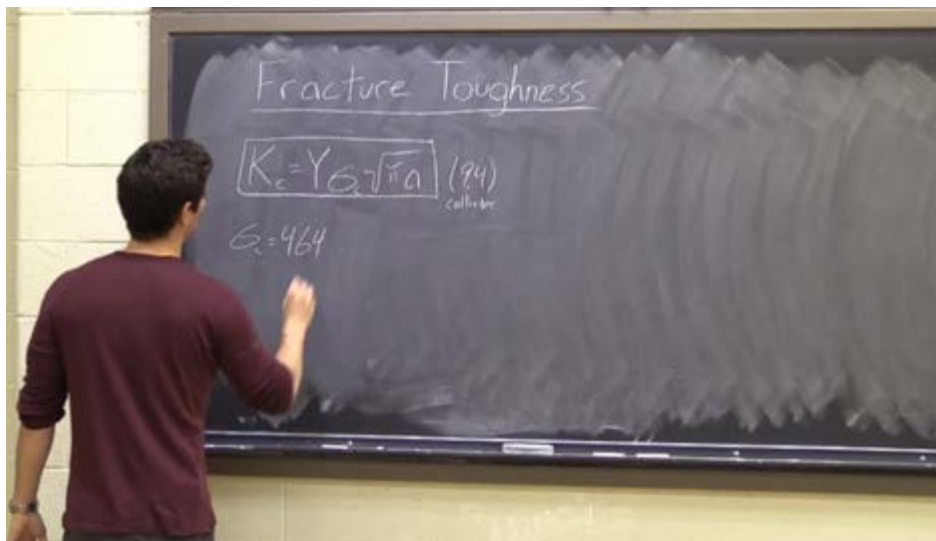


Figure 2: Still image of a graduate student video problem.

*c. Cornell notes, note-taking framework handouts*

The Cornell notes were based on the note-taking system devised in the 1950s <sup>[10]</sup>. The notes follow a systematic approach that encourages active learning, and, if used properly, may help convert short term memories into longer term memories <sup>[10]</sup>. In the present work, the instructor created a hybrid Cornell note design where the notes were partially populated with some section headings, key words, and basic diagrams such as axes for graphs, or wire-frame cubes for unit cells. This is considered a hybrid model because the original Cornell notes were typically entirely learner directed, meaning that students were responsible for writing their own keywords and questions <sup>[10]</sup>. Studies have evaluated the effectiveness of Cornell notes versus “free-hand” student notes. For example, a study conducted at Wichita State University by Jacobs et.al. <sup>[11]</sup>

found that students (n=58) with guided notes (similar to the present intervention) showed a larger improvement in quiz performance than those students who created their own notes free-hand. However, the students who took free hand notes performed better on higher-level questions. Students polled at Wichita State commented that they felt they had learned more using guided notes. Therefore, the authors concluded that both note-taking methods have the potential to be effective teaching and learning tools.

#### *d. Tempered glass lecture demonstration*

The tempered glass demonstration was included to demonstrate fracture properties but also to help students related materials science concepts to everyday life. Inside a large Plexiglas® box to ensure safety, a piece of tempered glass was shattered using a spring-loaded indenter. The demonstration shows how a crack in a material liberates new surface energy and since the tempered glass has a high stored elastic strain energy it breaks into very small pieces in a dramatic fracture event. This was an activity not feasible for tutorial or lab experiments due to safety and cost concerns. However, by including this demonstration in class, students could ask their questions real-time and test their hypotheses with the instructor; encouraging engagement more than a video could.

#### *e. Online homework problems*

Additional homework problems were added to the Blackboard portal for students to complete at their convenience if they felt they needed or wanted the extra practice. The questions were not marked and no grade was provided for their completion. These questions were aimed to complement the lectures, tutorials and assigned homework problems. In a study by Steif et.al<sup>[12]</sup>, students that participate in supplemental web-based courseware (completed more activities in an additional resource provided) tended to have higher exam scores, though a large group of students who did not use the additional resource did still receive high exam scores. However, the purpose of this Steif et.al study<sup>[12]</sup>, contrary to the present study, was to evaluate student self-regulation in their learning; those who didn't use the resource may not have needed it to further their learning<sup>[12]</sup>.

#### *f. New in-class slides for lectures*

New lecture slides were created as part of this study. A graphic artist was engaged to create new illustrations independent from the figures in the required textbook. The rationale for these new slides was that the students may benefit from exposure to a slightly different perspective on the topics. Of interest is the fact that this course is now taught entirely using the chalkboard, following focus group feedback and survey results showing a strong preference for instruction using the chalkboard, rather than PowerPoint. Amare, et.al <sup>[13]</sup> studied 4 groups of students (n=84); two groups of which were taught using traditional lecture materials (podium, chalkboard, handouts) while the other groups were instructed using PowerPoint presentations. Though students reported that they preferred PowerPoint, performance scores were higher in the sections with the traditional lecture format <sup>[13]</sup>.

## 2. Intervention Evaluation

In order to evaluate the use of the six RLOs, the study team used a combination of qualitative and quantitative techniques. Focus groups and surveys using the TopHat® classroom response system were employed to gather student perceptions, expectations and motivations when it came to adopting or not adopting these RLOs.

### i. Focus Groups

Focus groups were held in the winter of 2014 and run by a graduate student with extensive experience in focus group facilitation. All aspects of this study received ethics approval through the institution's delegated ethics review process. Two focus groups, of four first-year students each, were conducted, each lasting approximately one hour. Students were asked their impression of each RLO and encouraged to discuss their opinions of each activity including pros, cons and areas for improvement. Each session was audio recorded.

The inclusion criterion was enrollment in MSE101, the introductory materials science and engineering course being taught in the Winter 2014 semester at the University of Toronto. Students were not required to have used the RLO. Students were asked to participate on a voluntary basis only.

In addition to the audio recording, notes were taken during the session by the moderator. At the conclusion of the focus groups, the moderator transcribed portions of the audio recording to

facilitate the thematic analysis. Thematic analysis is an open –ended, iterative analysis of themes emerging from data without any imposed presuppositions. Themes related to each RLOs were noted, and suggestions, based on student feedback, for improvement were made.

### ii. TopHat® Surveys

TopHat® is a classroom and student response system where students can be asked questions (survey, polls, etc.) regarding lectures in real time using their own mobile devices (laptops, smart phones or tablets).

Approximately 20 questions were posed to students using TopHat®. The system allowed the instructor to keep the survey open for student feedback over a 4 day period to encourage participation at the students’ convenience. This timeline was chosen based on experience; the instructor did not expect feedback after 4 days without prompting students once more to complete the survey.

A variety of question formats were employed: yes/no, Likert scale format (strongly agree, agree, etc.) as well as free-form responses. Results were anonymized. A variation of the same four questions was posed regarding each RLO. See table 1 for the posed questions.

**Table 1: Sample questions from TopHat(R) survey**

<b>Questions posed in TopHat® Survey</b>
1. Did you watch/use the [RLO in question]?
2. I feel that the [RLO in question] helped me to learn the fracture topics better than if I had not used the [RLO in question]
3. I enjoyed the [RLO in question]
4. General Comments regarding the [RLO in question]

### iii. Student grades before and after semester of RLOs

Finally, a quantitative method for evaluating the use of RLOs was employed. The study investigators sought to compare the semester averages of students who employed individual



RLOs versus the students who did not. The hypothesis was that students who employed any RLO would perform better than students who had not. A one-way analysis of variance (ANOVA) was employed using the statistical software SPSS Software 19.

The study team also sought to compare historical class averages (seven semesters) with the class averages of students who had been provided with the RLOs (three semesters). Again, the hypothesis was that semester averages where students had access to the RLOs would be higher than historical averages. A one-way analysis of variance (ANOVA) was employed SPSS Software 19.

## **Results**

### i. Focus Groups

Themes that emerged from the focus groups were grouped by individual RLOs.

1. Online “Khan Academy Style videos (KSV)”, 2. Example problem videos by graduate students, 3. Cornell notes, note-taking framework handouts, 4. Tempered glass lecture demonstration, 5. Online homework problems, and 6. New in-class slides for lectures.

#### *a. Online “Khan Academy Style videos (KSV)”*

Of the eight students who participated in the study, most found the fracture synopsis videos to be concise and helpful for a quick review of challenging concepts. The fact that the videos were short was a distinct advantage. However, these videos were introduced later in the semester as a means of review; students wished that they had been made available earlier to complement their first experience learning the topic.

#### *b. Example problem videos by graduate students*

The example video problems were considered very helpful to the students as it gave them the freedom to learn and practice problem solving at their own pace. Students felt there was a need for more video problems in the course to explain both additional fracture concepts as well as other topics.

#### *c. Cornell notes, note-taking framework handouts*

Those who attended the focus groups preferred taking their own notes to using the Cornell notes. They felt that the notes didn't necessarily follow the order of the lecture and therefore did not enhance their learning of the topic. However, the moderator realized that the purpose of Cornell notes was not well understood; students assumed that they were a different set of lecture slides rather than a method to summarize and synthesize concepts to reinforce learning. This may have contributed to their negative reception.

*d. Tempered glass lecture demonstration*

The tempered glass demonstration was highly regarded by the students who felt that they understood the concepts much better after having seen the demonstration in class. They found this and other demonstrations to be very engaging and entertaining and better for concept retention. Furthermore, students felt demos were more valuable than laboratory sessions included in the course curriculum. Students did not consider labs helpful, since they watched the teaching assistant demonstrate an experiment rather than getting the chance to perform the experiment themselves. Students felt that labs could be easily replaced by videos.

*e. Online homework problems*

The students did not readily comment on the online homework problem RLO. They felt it was just additional work that didn't necessarily offer a new perspective from which to learn. However, this is contrary to some of the TopHat results, which examined a larger population of students. This will be discussed further below.

*f. New in-class slides for lectures*

When asked about the lectures slides, comments included students expressing a preference for chalkboard teaching rather than PowerPoint slides.

Some general comments were that the RLOs were difficult to locate as there are a number of places they could be: instructor's personal site, Blackboard site, etc. The opportune time to look up the RLOs as well as their location will be better addressed in the next semester.

ii. TopHat® Survey Results

As mentioned above, a TopHat survey was disseminated to all students to gather their perceptions of the six RLOs at the end of the Fall 2013 semester. Question format included both yes/no questions as well as Likert scale questions; for example in answering a question related to perceived usefulness (Figures 3-5).

Of the 241 students enrolled in the course, there was a 49% response rate (n=118).

*a. Online “Khan Academy Style videos (KSV)”*

Regarding the fracture synopsis videos, 64% (n=65/102) of students who completed the survey reported that they watched them and 75% (n=48/64) of those who had watched the videos found them helpful to their learning. Of those who watched, 70% (n=45/64) of them either agreed or strongly agreed with the statement that they enjoyed watching the videos.

*b. Example problem videos by graduate students*

Of the 72 respondents who answered these questions, 28% (n=20/72) reported having viewed the examples problems and 75% (n=15/20) felt that the problems were more helpful in learning fracture topics than if they had not viewed them. Of those who viewed the examples, 75% (n=15/20) agreed or strongly agreed with the statement that they enjoyed the videos.

*c. Cornell notes, note-taking framework handouts*

The Cornell notes had a particularly low uptake rate with only 4.3% (n=4/94) of respondents reporting having used them. Of that group, 50% (n=2/4) of them felt that the use of the notes helped them learn Fracture better than not using them. Of those who used the notes, 25% (n=1/4) of them agreed that they enjoyed using the notes.

*d. Tempered glass lecture demonstration*

The tempered glass demonstration yielded the most positive responses from students. Of the 90 students who answered the questions related to this RLO, 92.2% (n=83/90) of them reported that the demonstration increased their curiosity about fracture principles, while 84% (n=73/87) reported that the demonstration helped them learn the topic more than if they had not seen the demo. When asked to rate their enjoyment of the demonstration on a Likert scale, 89% (n=82/92) agreed or strongly agreed that they enjoyed the demonstration.

*e. Online homework problems*

As mentioned above, additional homework problems were posted on the course's Blackboard site. Some 10% (n=9/90) of respondents answered that they had attempted the online homework problems before the relevant class. Of these, 56% (n=5/9) said that the questions helped them learn fracture better than not trying the problems. Approximately 56% (n=5/9) of those who attempted the problems agreed or strongly agreed that they enjoyed the problems.

*f. New in-class slides for lectures*

Finally, students were asked their opinion of the new fracture lecture slides. When asked if the new fracture slides were better compared to the previous PowerPoint lecture slides based on the textbook figures, 71% (n=54/76) of respondents agreed. These notes, as mentioned above, were designed independently of the required textbook; 84% (n=61/73) agreed that the new slides helped them learn material better than if the slides were based directly on the textbook. Some 81% (n=56/69) agreed or strongly agreed that they enjoyed the new fracture lecture slides. Please see Figures 3-5 for complete results of TopHat survey.

iii. Student grades before and after semester of RLOs

Included in the TopHat® survey was a request for student permission to capture their final semester grade. The TopHat® data was analyzed by two graduate students not affiliated with the course; therefore, before anonymizing the data, the graduate students were able to link those who had responded to the survey with their final class grades. The class averages of students who had used each individual RLOs were compared against the averages of those who had not used the interventions. The SPSS software was utilized. The only significant ( $p < .05$ ) difference was seen between those who had viewed the demonstration (average 78%) in class versus those who had not (average 73%;  $p = .004$ ).

In addition to this, 7 semesters' worth of averages prior to the intervention were compared to the three semesters where the interventions had been available for use. No significant difference was observed.

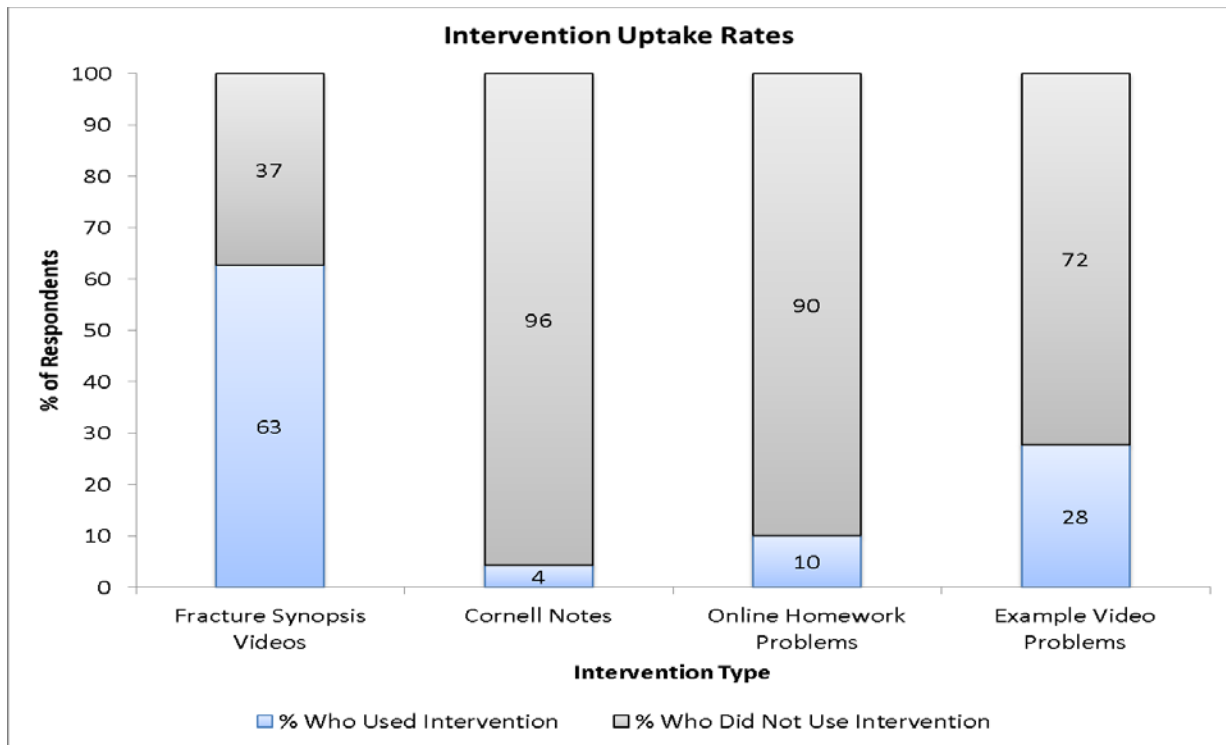


Figure 3: Intervention Uptake Rates based on TopHat(R) survey responses

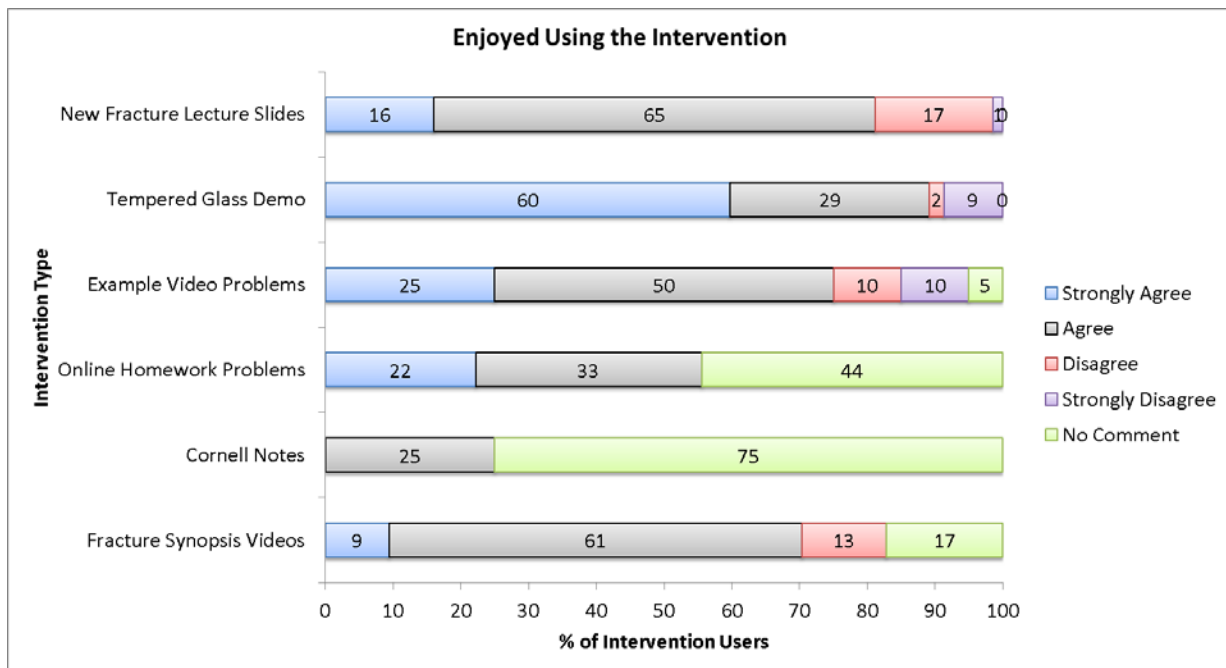


Figure 4: Student responses regarding enjoyment of interventions based on TopHat(R) survey responses

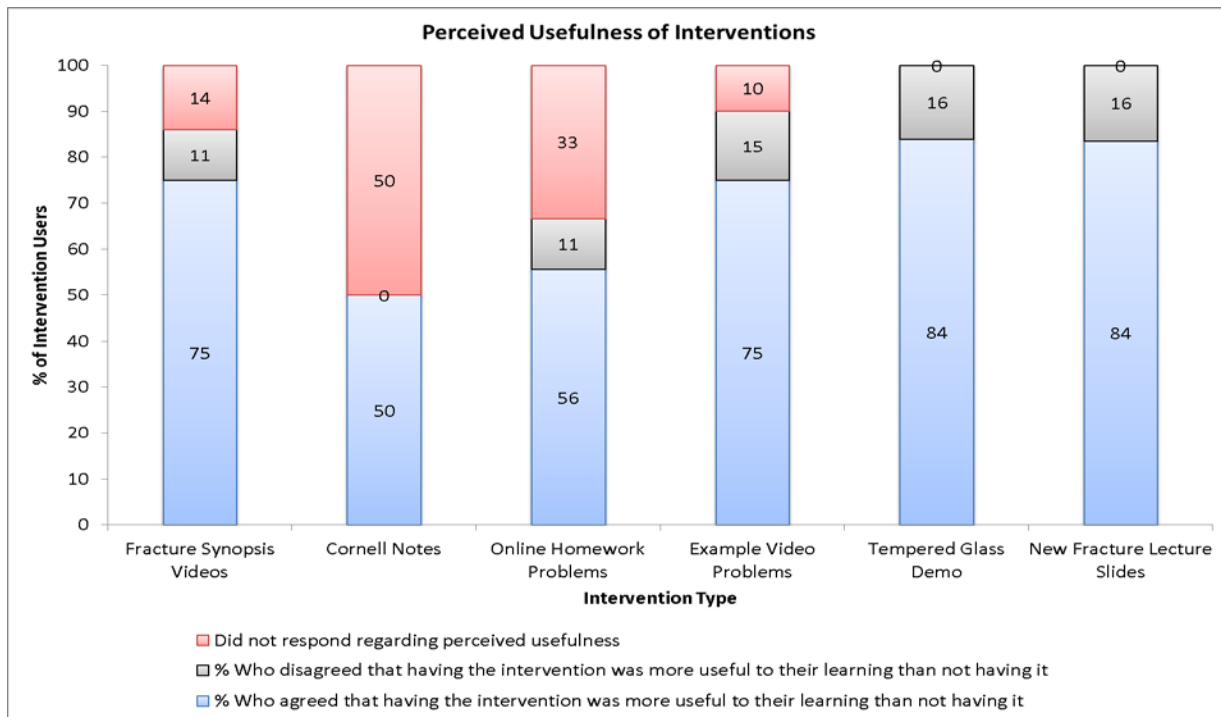


Figure 5: Student perceived usefulness of interventions based on TopHat(R) survey responses

## Discussion

### 1. Performance vs. Preference

Several facets of the interventions were analyzed in this study: exam performance based on the use of the interventions as well as preference. As alluded to in the Amare, et.al<sup>[13]</sup> study, preference does not necessarily translate to increased performance; in other words, a performance vs. preference paradox exists. For example, students preferred the fracture synopsis videos (i.e., it had the greatest uptake), though no significant improvement in exam performance was observed.

Here, the objective and subjective metrics seemed to conflict. Though students' understanding did not necessarily improve, they preferred the online "KSV". Contrary to this, 84% of students agreed that the tempered glass demonstration was useful to their learning and those who observed the demonstration did perform better in the course than those who did not; here, the

objective and subjective metrics agree. However, this result may well have been due to a bias in the students who viewed the demonstration towards students who also regularly attended lecture.

The practical take-away from this study was that both user opinions and preferences are valuable data that should be taken into account when choosing to include interventions in the curriculum.

Another interesting observation was made regarding the Cornell notes. They were not perceived as useful and there was very little uptake; however, through discussion with students, the instructor learned that some of the students who did use the Cornell notes as intended found them very valuable to their learning. Also, despite the low uptake rate, of the students reporting having used the Cornell notes, 50% felt they were useful and 25% actually enjoyed using them. Given the low marginal effort required to post the Cornell notes, once created, it seems worthwhile to continue to make them available for the small number of students who do benefit from them.

## 2. Key Lessons for Future Work

Therefore, based on the results described above and the instructor's experience, some decisions can be made regarding which interventions should remain incorporated in the course and which should be discontinued. The decisions to keep an intervention are based on the overall effect on students and the effort by the instructor and graduate students to plan, create and conduct these RLOs.

Because of the high uptake and students' opinion of its usefulness, online "KSV" videos will remain included as supplemental materials for the course. The same is true of demonstrations; in fact additional demonstrations have been included in other parts of the course and will continue to be refined to emphasize difficult concepts. The illustrations used in the new lecture slides will be used to supplement online text-book style content being created, since the chalkboard is now being used exclusively for lecture delivery.

Though the Cornell notes did not poll very favourably, they will remain available to students and student will be encouraged to try them out, at least at the beginning of each term. Other than minor changes due to curriculum changes or formatting, the notes remain largely unchanged from one year to the next. Furthermore, additional instructions will be provided next semester when Cornell Notes are introduced to the students.

The online homework problems and the online video problems took considerable effort to produce and disseminate to students, and given the only modest responses from students the inclusion of online homework problems and video example problems will be avoided and resources will be redirected towards the creation of other RLOs, like the KSVs and lecture demonstrations.

## **Conclusion**

In conclusion, RLOs were found to be an effective and engaging method for supplementing core didactic teaching in a first year Materials Science and Engineering course. Generally, students felt that the course was very good at catering to many different learning styles. Based on the survey and focus group response, further adjustments will be made to the curriculum to better meet student expectations and needs. This reinforces the importance of rapidly evaluating and iterating intervention design. Student engagement in RLO design and evaluation is key to RLO success and in generation of new ideas.

There are a number of opportunities to continue to evaluate the effectiveness of these interventions. The study team is looking to evaluate retention of materials concepts taught in first-year as the students move through their engineering undergraduate degree. This will allow the authors to determine whether these interventions have reinforced course material more substantially than in students who did not use them.

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