Development of Interactive Hands-On Lecture Demonstrations for Fundamentals of Mechanics in Large Class Sizes

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CONTEXT

In the large UNSW stage 1 course ENGG1000 – Engineering Design and Innovation, Semester 1, 2015 and Semester 1, 2016; there were approximately 1400 enrolments per semester. The largest single engineering project offered within the course is the Mechanical Engineering project with approximately 280 students joining the project in Semester 1, 2016. In Semester 2, 2015, ENGG1000 student enrolments were 380 with almost 50% selecting the project offered by Mechanical Engineering and approximately 50% of students taking the Mechanical Engineering technical stream (a significant number of students chose both the Mechanical Engineering project and stream).
The Mechanical Engineering project of ENGG1000 delivers information to students via large class size lectures. The concepts discussed during lectures are further reinforced through tactile learning in three hardware demonstration labs.

PURPOSE

This work focusses on personalising the teaching experience and increasing student engagement in the large scale stage 1 course, ENGG1000 – Engineering Design and Innovation. The demonstration items developed in this work provide kinaesthetic learning opportunities for delivering improved, personalised large scale teaching and employing the items in visual media to improve large scale assessment and feedback. The initial work is concentrated on the Mechanical Engineering project but it is planned to incorporate some of the techniques and findings into the common lectures of the course.

APPROACH

Multiple hands on demonstration items have been designed, manufactured and implemented, covering various areas such as angular displacement, fasteners, how gears mesh, belt and pulley systems, bearings etc. This has enabled a more engaging approach by which lecture material on fundamentals of mechanics is presented to first year students. The demonstration hands-on items were incorporated into the online hardware assessments and incorporated into an Instant Corrective Feedback (ICF) system that highlights incorrect responses made during a quiz and demonstrates the correct functions of the component or system.

RESULTS

In general, the interactive hands-on demonstration teaching aids were very well received and considered to be more engaging by students than traditional lecture styles. Approximately 73% of students found the interactive demonstration items to enhance their learning experience. The ICF style of online assessments were also preferred by students with analysis of student feedback suggesting up to 75% of students preferred this style of online assessment.

CONCLUSIONS

Analysis revealed that the majority of students found the interactive demonstration items and ICF assessments to enhance their learning experience.

KEYWORDS

Large class sizes, kinaesthetic learning, tactile learning, instant corrective feedback.

Project Aims and Methodology

Project Aims

This project focussed on personalising the teaching experience and increasing student engagement in the large scale UNSW first year course, ENGG1000 – Engineering Design and Innovation. The course functions as an introduction for new students to an engineering degree and parts of the course introduce engineering concepts, ensuring all students have a solid underpinning for the remainder of their degree. As a core first year course, the student body is necessarily larger than most other subjects, presenting unique challenges for ensuring the transfer of knowledge to the entire cohort.

Many scientific concepts can be difficult to comprehend when presented verbally or statically, but can be grasped very quickly and better retained when experienced through direct interaction (Glass, 2003). Additionally, presentation of concepts through a variety of processes such as theoretical accompanied by practical is known to assist in reaching a broad range of student types more effectively (Felder, 1988). The demonstration items developed in this project provide kinaesthetic learning opportunities for delivering improved, personalised large scale teaching and employing the items in visual media to improve large scale assessment and feedback.

Whilst students do have separate hardware related laboratories in this course, this work utilises approaches to fuse together lectures with in class hardware hands-on demonstrations and incorporate online assessments with instant corrective feedback.

Project Methodology

The Mechanical Engineering project of ENGG1000 delivers information to students via large class size lectures, which can be a hurdle for ensuring student retention (Felder, 1988). The focus was to improve student learning interactively, augmenting lecture theory presentation, a teaching method already known to be effective (D Mazzolini & Daniel, 2012) (Sokoloff, 1997). In addition to the lectures, the concepts discussed during lectures are further reinforced through tactile learning in three hardware demonstration labs. As the class size is usually 280 students, the opportunity is to personalise the teaching experience for students by developing hands-on demonstration items that can be circulated in class to synergistically support the lecture material being presented.

The following approaches were utilised and rolled out in Semester 1, 2016.

1. Development of a range of hands-on teaching demonstration items with each targeting one or more specific mechanical engineering concepts.
2. Implementation of the interactive portable demonstration items during lectures to aid in explaining the engineering concepts.
3. Further use of the interactive demonstration items during three Hardware Laboratories.
4. Development of instant corrective feedback (ICF) for the online assessments in the course.

Where possible, hands-on or interactive aids have been assembled that demonstrate one or more of the concepts discussed in the course material. Due to the introductory, fundamental nature of the course, emphasis has been placed on designing teaching aids to avoid excessive complexity. Instead, the aids are tailored to show a few concepts as clearly as possible, with emphasis placed on focussed and/or contextual significance.

Written material involving the interactive aids has been developed and incorporated into existing course assessments, and where the new assessment material is used, the assessment procedure has been updated to include an Instant Corrective Feedback (ICF) element to enhance the teaching aspect of the work. Results from the ICF assessment elements has been analysed to examine its effectiveness as a teaching tool.

Development of Physical Interactive Teaching Materials

Concept

The project has delivered several hands-on and interactive teaching aids of various sizes and functions. These aids accompany the course's existing lecture material, augmenting the verbal and written presentation with physical demonstration.

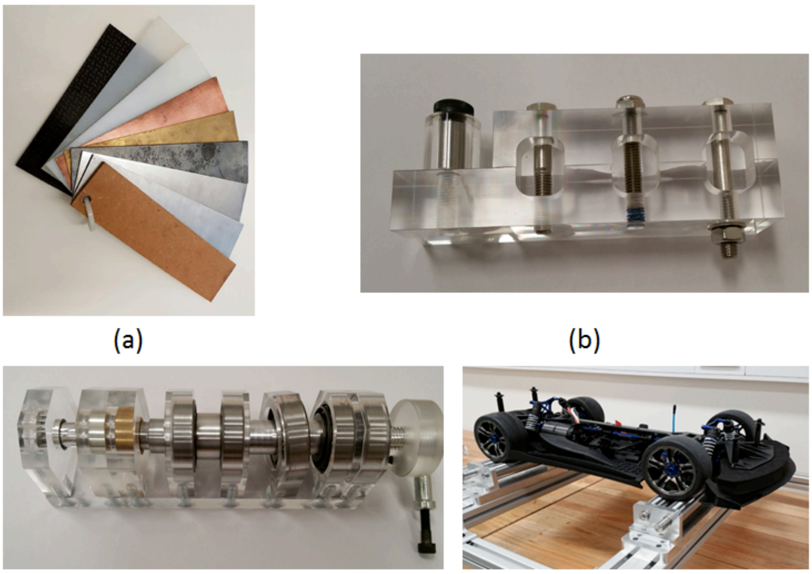
The aids are dynamic and/or interactive. They have been set up to highlight specifically the mechanical features they are attempting to demonstrate; superfluous material has been designed out of the aids to eliminate any distractions from their targeted teaching goal.

Various aids consolidate a range of concepts into a single source where real-world examples would require multiple examples. This allows quick and easy comparison between various similar technical options in a single source. Other aids are closer to real-world examples, designed to show a variety of mechanical functions interacting with each other in a realistic setting including specification, tolerance and manufacturing methods.

Execution

The existing course material was examined and wherever an engineering concept was found that could be succinctly demonstrated through an interactive physical medium, a concept was designed along with supporting documentation detailing conceptually significant features of the design. In conjunction, whenever an existing apparatus was found that could be easily adapted for use that already fulfilled appropriate demonstration criteria, the apparatus had demonstration protocols and documentation regarding it developed.

Examples of the types of physical teaching aids developed can be seen in Figure 1.



(a) (b) (c) (d)

Figure 1: Examples of hands-on teaching aids developed for this project. (a) Material samples, (b) bolts teaching rig, (c) bearings teaching rig and (d) RC car dyno.

Of the samples shown in Figure 1, the materials samples, bearing and bolts rigs are examples of custom-designed teaching apparatus aimed at teaching a single concept covered in the course material. Each shows multiple different examples of a single engineering concept; materials, bearings and bolts. For example, the bolts rig illustrates to the student some of the possible bolt and nut options when designing a threaded fastener connection.

These rigs serve to demonstrate to the student that there are a wide range of options available to solve an engineering problem, different options can be beneficial depending on the context, and it is important for the student to be familiar with the different options when approaching an engineering problem. It also helps familiarise the students with basic terminology and material.

By contrast, the RC car dynamometer (“dyno”) is an example of adapting an existing apparatus to the interactive teaching aids. The car had already been in use in front of the students as its mechanical components are an excellent compilation of concepts (materials, linkages, springs, gears and so forth) interacting with each other. The car had a rolling road designed and built for it allowing it to be driven live in front of the students, allowing the components to be displayed interacting with each other dynamically.

In addition to each physical apparatus, illustrated notes were generated identifying the key features of each design. These notes serve as teaching guides for demonstrators, and when appropriate are distributed among the students during demonstrations to allow them to better grasp the features presented. These notes also served as a key feature of the digital interactive teaching materials.

Each of the physical teaching aids and corresponding notes were passed around or live demonstrated during lectures (depending on portability and ease of operation), and were then later presented again during interactive hardware lab assessments. By repeated access with no fixed time limit, each student is ensured access to any aid for a sufficient time to allow them to become familiar with its features and associate these features with the attached theoretical concept.

Development of Digital Interactive Teaching Materials

In addition to use in lectures, the developed kinaesthetic teaching materials were incorporated into three existing course assessments referred to as “Hardware Labs”. These labs give students first-hand experience with real-world engineering items such as shafts, gears etc., whilst requiring them to fill out a question sheet on the items. The students are then required to complete an online assessment quiz based on the question sheet.

Wherever the quiz had been adapted to the newly developed teaching aids, the online assessment was modified to allow an Instant Corrective Feedback (ICF) mechanism. The ICF mechanism allows the student a second attempt at an incorrect quiz answer after presenting them with technical documentation regarding the object in question to help them determine the correct answer. The logic of the ICF process is shown in Figure 2.

The documentation developed during the design of the physical teaching aids was easily adapted into digital format appropriate for student presentation. This material was scripted to supply targeted information and not to simply supply the correct answer. Additionally, whereas alternative systems simply gave students a second attempt to answer a question (Cotner et al, 2008) this system encourages the students to read through relevant technical material, enhancing their comprehension and demonstrating the importance of perusing technical documentation, a habit that is beneficial to develop in their early stages of tertiary studies.

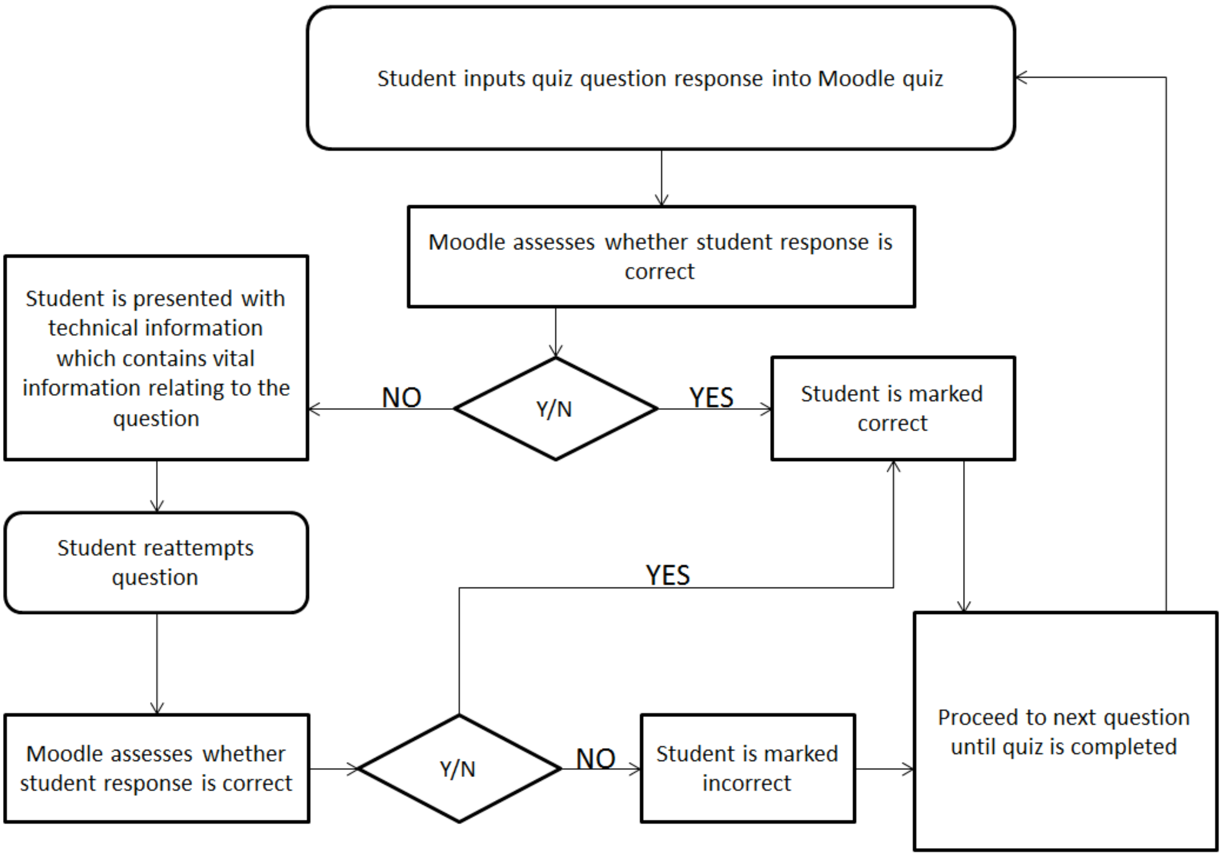


Figure 2: Instant Correct Feedback procedure

Evaluation of Interactive Teaching Systems

It was important to evaluate the success of the implemented teaching aids. To do so, subjective and objective assessment metrics were established. Attached to each ICF quiz was a questionnaire for the students regarding their reactions to the quiz and material presented to them. The students' subjective answers were analysed to determine overall trends in opinion towards the material. Additionally, the student marks were analysed and comparisons taken between ICF and non-ICF enabled quizzes to objectively assess the effect of the ICF process on student learning.

Subjective Evaluation

Most students reported positive involvement compared to more traditional teaching tools. Figure 3 illustrates the responses of the students on whether the interactive teaching aids used in the course lectures/demonstration were helpful.

From Figure 3 it can be clearly seen that the majority of students reported finding the interactive teaching aids helpful. In fact, 73% of students found the interactive teaching aids to be helpful in their learning of the course material.

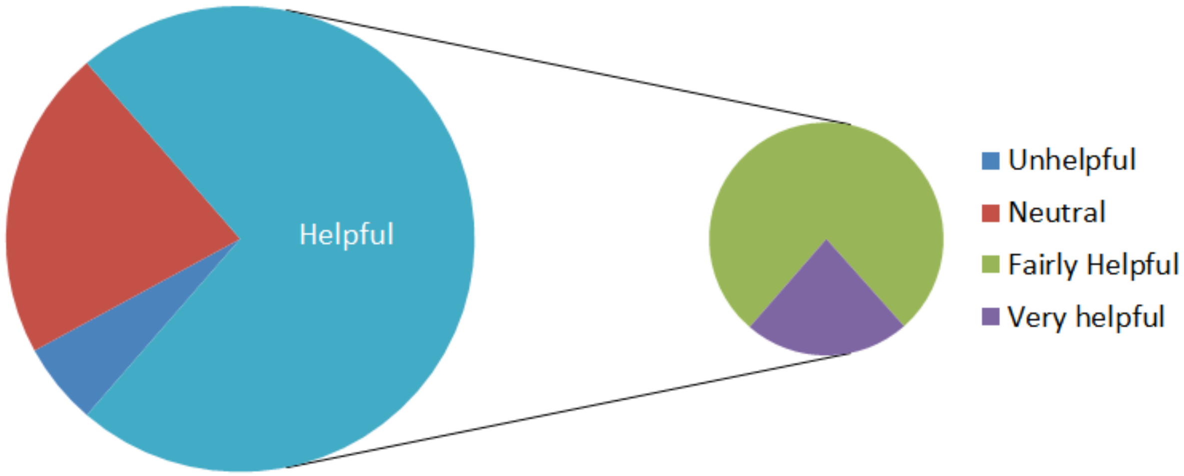


Figure 3: Students responses on whether they found the interactive teaching aids helpful

Figures 4a and 4b show the response of students on whether the ICF style of quiz improved their learning experience for hardware lab 1 and 3 quizzes respectively.

From Figure 4 it can be seen that over 75% of students stated that they found the ICF style of quiz to improve their learning experience in hardware lab 1 (Figure 4a) and over 60% for hardware lab 3 (Figure 4b). No feedback data was recorded regarding ICF material for quiz 2 as feedback questions targeted different information to quizzes 1 & 3.

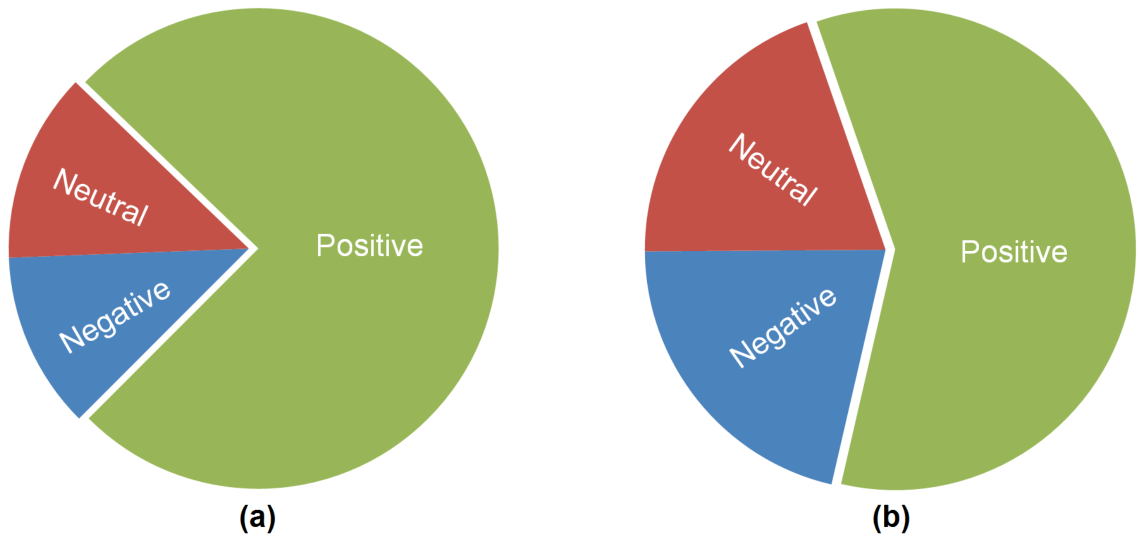


Figure 4: Student's responses on whether they found the ICF style of quiz to improve their learning experience (a) hardware lab quiz 1 and (b) hardware lab quiz 3.

Objective Evaluation

The ICF (part B) component of each quiz was worth 20% of the total quiz for hardware lab 1, 20% for hardware lab 2 and 30% for hardware lab 3. In addition, the difficulty for each ICF ranged from easy for hardware lab 1, difficult for hardware lab 2 and medium for hardware lab 3.

In hardware lab 1 the instant corrective feedback was specifically targeted to provide clear information towards the correct answer to students submitting an incorrect response. In hardware lab 2, the feedback information was more generic and students had to filter through significantly more information than hardware lab 1. In hardware lab 3, the information provided in the feedback given to students for incorrect responses was targeted and of a more illustrative nature.

The difference in the average student scores for the ICF and non-ICF component of each quiz is shown in Figure 5. It can be seen that, regardless of the targeting method used for the feedback questions, an improved result is achieved in the ICF sections. Similarly, regardless of the average difficulty of the question set, the ICF system enables better student comprehension.

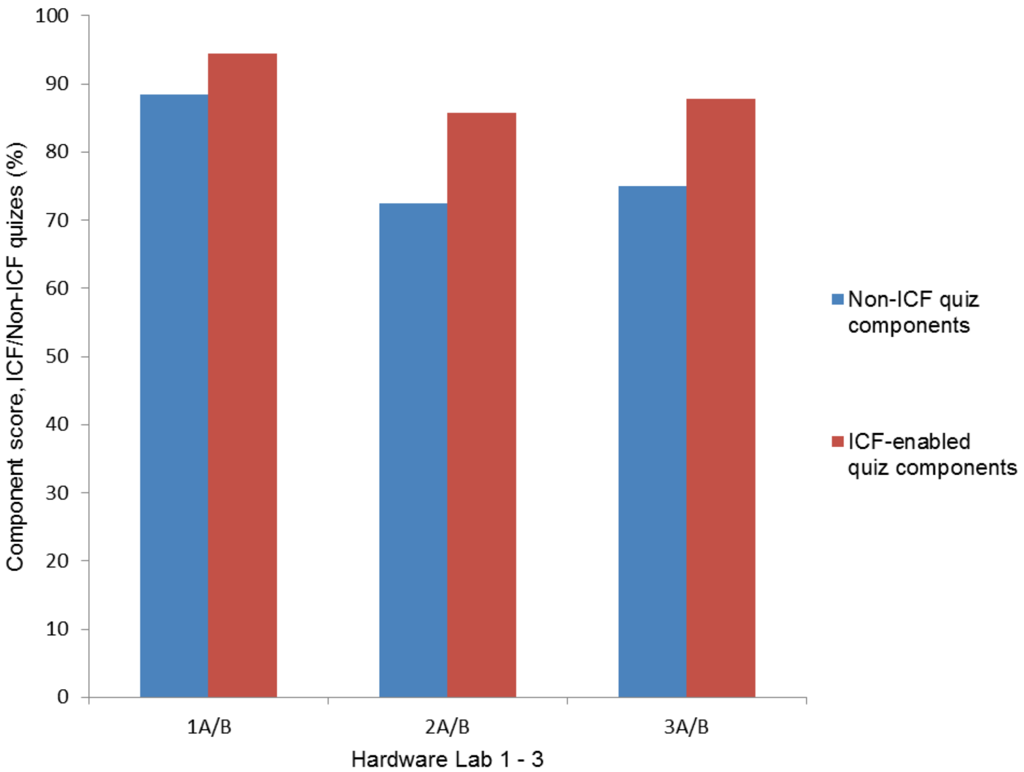


Figure 5: Comparison between ICF and non-ICF average mark for each hardware lab quiz

From Figure 5 it can also be seen that the average score for all labs was high for the ICF component relative to the corresponding non-ICF component. Random data sampling suggests that approximately 75% of students used the ICF system in a meaningful way, either using the material to correct a mistake or consulting the material for extended durations. Histogram analysis of student marks showed that least consistent marks were achieved by responses that took less than three minutes or longer than twelve minutes to complete the quiz, i.e. groups which could be interpreted as either not taking the time to read ICF material properly or that failed to comprehend it regardless.

While there are many uncontrolled factors such as relative difficulty of questions and transparency of feedback information, all results showed that ICF questions have more consistency and on average higher correct response rate from the students. The difference in the average mark between non ICF and ICF quiz components for labs 1, 2 and 3 ranged from 6% for lab 1 to 13% for labs 2 and 3, with a significant reduction in the spread of marks between non-ICF and ICF for each quiz. Current analysis suggests that students consistently answered more questions correctly in the ICF quiz components, and appeared to learn more in the process.

Conclusions

This project has demonstrated the value of interactive visual aids in enhancing the student learning experience in a large class size environment. Student feedback showed that up to 73% of students found the interactive teaching aids helpful in enhancing their learning experience and 75% of students preferred the Instant Correct Feedback style of quiz.

The development program undertaken in this project will continue with further demonstration items planned to enhance the student learning experience on a long term basis. Expansion of the implementation of interactive teaching aids into further large class size courses is planned. An investment into further aids for tactile learning will ensure that the kinaesthetic teaching aids developed will adapt with the continually adapting course material.

Further ongoing analysis of student feedback and results will be used to target opportunities for future improvement.

References

Cotner, S.H., Fall, B.A., Wick, S.M., Walker, J.D., & Baepler, P.M. (2008). Rapid Feedback Assessment Methods: Can We Improve Engagement and Preparation for Exams in Large-enrollment Courses? *Journal of Science Education and Technology*, Vol 17, Issue 5, 437 - 443.

Felder, R. M., & Silverman, L. K. (1988). Learning and Teaching Styles in Engineering Education. *Engineering Education 78.7*, 674-681.

Glass, S. (2003). *The Uses and Applications of Learning Technologies in the Modern Classroom: Finding a Common Ground Between Kinaestehetic and Theoretical Delivery.* ERIC.

Mazzolini, A. P., Daniel, S., & Edwards, T. (2012). Using interactive lecture demonstrations to improve conceptual understanding of resonance in an electronics course. *Australasian Journal of Engineering Education, Vol 18, No. 1*, 69 - 88.

Sokoloff, D. R., & Thornton, R. K. (1997). Using interactive lecture demonstrations to create an active learning environment,. *The changing role of physics departments in modern universities. Vol. 399. No 1.* College Park, Maryland (USA): AIP Publishing.

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