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Contextualizing Learning Chemistry in First-Year Undergraduate Programs: Engaging Industry-Based Videos with Real-Time Quizzing

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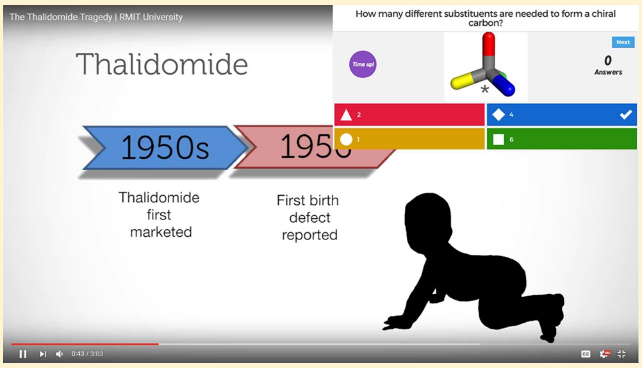
Ⓢ *Supporting Information*

ABSTRACT: First-year undergraduate classes present challenges in teaching as they usually have high student enrolment numbers and students studying across a range of higher education programs that require a fundamental understanding of knowledge that is not perceived in their area of study. This provides a challenge in terms of engaging and maintaining student interest, primarily because students do not recognize the application of knowledge to their field of study. The challenge is to contextualize the content for the range of student cohorts within the one course. This is a common issue within many of the programs offered at RMIT University, Melbourne, Australia. The teaching pedagogy and learning design pattern developed address the implementation of activities that incorporate the flexible delivery of content, including online media-rich interactive learning via the creation of short videos, to illustrate the direct application and relevance of the content and thereby capture student interest and increase their motivation to learn. It also includes formative feedback to students via real-time student quizzing. In this case study, seven YouTube chemistry videos were created for a first-year undergraduate chemistry course. The videos created needed to be short, sharp, and engaging and were based on relevant chemistry topics taught. Each video created also included at least one Australian-based industry to give real-life relevance and focus as well as tailor them to the local student cohort.



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■ INTRODUCTION AND BACKGROUND

Improving the learning experience and involving students in the learning process are critical for lifelong learning and in promoting a knowledge economy. Research has shown that students learn far more deeply from words and pictures than solely from words alone.[1]

Active learning, through which students become active participants in the learning process, is an important means for the development of student skills in that it encourages talking, listening, writing, and reflecting.[2,3] These four elements involve cognitive activities that allow students to clarify, question, consolidate, and appropriate new knowledge.[3,4] Videos and games, in particular, provide a diverse approach to the learning process and outcomes.[3] They allow for peer feedback in collaborative learning, address learning issues, and foster active learning.[3,5]

Use of videos in science education has been successful in overcoming problems that cannot be eliminated using traditional teaching methods (e.g., understanding and conceptualization difficulties and misconceptions).[6−10] Videos facilitate learning by allowing students to animate abstract chemical concepts in their minds[6,11−18] and make it easier for students to remember the important points of the subject matter.[6,19] Videos have a positive impact on acquiring knowledge[6,20,21] and contribute to the development of a student's cognitive capabilities including interpreting, critical thinking, and problem-solving skills.[22,23] The use of videos as teaching material also has a positive impact on a student's motivation.[6,19,22]

It has become increasingly more common to find videos of chemistry experiments, animations and simulations that explain abstract chemistry concepts, especially on YouTube,[6,24−28] thus making students' conceptual learning of chemistry much easier.[29] Making use of videos in a teaching environment has changed the styles of teaching.[6] Instead of remaining passive, students actively participate in the learning process (e.g., problem-solving, knowledge building) in the classroom.[6,30,31]

In the video production process, consideration needs to be given to "the content of the video, the chemistry knowledge to be offered, the use of suitable and effective images, and the length of the video." To this end, "the teacher needs to have technological pedagogic content knowledge."[6] Student-cen-

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Table 1. Overview of Chemistry Videos Created

	Video Number and Title	Australian Industry Involvement	Views, N[b]	ref[c]
1	The Tragedy of Thalidomide	Therapeutic Drugs and Administration (TGA)	814	40
2	The Sweet World of Carbohydrates	Australian Sugar Milling Council, and Sugar Research Australia	195	41
3	Insulin: The Holy Grail of Diabetes Treatment	Diabetes Australia	4922	42
4	Conotoxins: Mastery of Painkilling Medicines from Nature	Institute for Molecular Bioscience (IMB), University of Queensland, and Invitro Technologies Pty Ltd.	142	43
5	The Science of Making Margarine	Australian Oilseeds Federation, and Australian Institute of Food Science and Technology	122	44
6[a]	The Chemistry of Pressure Cooking	William Angliss Institute (WAI)	43	45
7[a]	Cisplatin: The Role of Platinum in Cancer Treatment	Peter MacCallum Cancer Centre	44	46

[a]These videos were completed at the end of 2015 and were released for the first time in 2016. [b]Number of views of videos as at May 12, 2017. [c]See the references for video URLs.

tered teaching approaches engage learners in constructing knowledge through activities such as problem-based learning and collaborative problem solving. These types of practices enhance student success, result in more effective learning than traditional methods, and are not discipline dependent.[32−34]

The use of videos and games in chemistry teaching can facilitate a range of active teaching pedagogies that can be tailored to the instructor.[35−37]

RATIONALE AND FOCUS

First-year classes with large student enrolments where students study across a range of higher education programs require a fundamental understanding of knowledge that is often not perceived in their area of study. This provides a challenge in engaging and maintaining student interest and contextualizing the content for the range of student cohorts within the one course.

For example, students enrolled in the first year CHEM1239 Chemistry for Life Sciences course offering at RMIT University, Melbourne, Australia are studying across a number of separate programs (e.g., food technology and nutrition, biotechnology, biotechnology and biomedicine), which requires them to have a basic understanding of chemistry principles. An opportunity to engage student interest by illustrating relevant examples that are related to their area of study and provide a local industry connection was recognized. It was realized that this would also provide an alternative method and delivery of highlight key concepts taught in a chemistry course.

PROJECT DESCRIPTION

Research Design

The aim was to apply innovative educational technologies to improve student learning outcomes such as enhancing the student cohort experience by illustrating relevance of course content; anticipated student retention by engaging student interest; and re-evaluating ways to make the content interesting and relevant to the individual student. It was also anticipated that this would improve student comprehension, retention, and overall performance, which would lead to a positive impact in the Course Experience Survey (CES) and Good Teaching Score (GTS), which are used to monitor teaching success in Australian Universities. The CES is administered by the Student Services Centre (SSC) at RMIT University to help academic and teaching staff to obtain feedback about their courses and contribute to the improvement of student learning. The GTS measures students' perceptions of teaching standards. It focuses on teachers' feedback, motivation, attention, understanding of problems, and skill in explaining concepts. High scores on this scale are associated with the perception that there are good practices in place; conversely, lower scores reflect a perception that these practices occur less frequently.

The goal was to create a series of short chemistry videos to supplement the explanation of certain topic areas and applications taught in this course. To aid in the contextualization and to fill an important teaching gap, the videos were created for the Australian student cohort by inclusion of an Australian industry.

The Student Cohort

Chemistry for Life Sciences (CHEM1239) semester 2, 2015 (138 students) and semester 2, 2016 (164 students) were composed of students studying across several programs and were taught in a face-to-face context. The course comprises the units of organic, physical, and inorganic chemistry, and within each unit curricula there are a series of topic areas.

METHODOLOGY

The learning design pattern developed addresses the implementation of activities that incorporate the flexible delivery of content, including online media-rich interactive learning via the creation of short videos. The learning design pattern illustrates the direct application and relevance of the content to capture student interest and motivate learning.

The learning outcome was to foster and enhance the student learning experience in nontraditional chemistry disciplines. In the development of this learning pattern, a total of nine key process activity steps were identified:

(1) Identify topic area where inclusion of video content will enhance learning.
(2) Identify any similar online products and identify any gaps in content areas (e.g., Australian industry focus).
(3) Develop a storyboard for the proposed video addressing the key topic area utilizing a content expert (e.g., a lecturer with expertise in the area).
(4) Identify and approach potential Australian industry contributors to create the video.
(5) Create video as per storyboard. Consider appropriate options when deciding on how the video is to be made (e.g., video can be created using a range of options such as in-house development using appropriate software such as Adobe Premier CC or outsourcing production—internal or external to university).

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J. Chem. Educ. XXXX, XXX, XXX−XXX

(6) Seek academic peer review and feedback of videos particularly of the content/concept (mainly with project team members and other academics in the relevant area).
(7) Identify the most appropriate means to implement videos for students to engage (e.g., linked as part of the learning management system Blackboard Learn site or via YouTube release).
(8) Seek student feedback (via quizzes, survey, and CES). Use gaming Web sites like Kahoot.it[38] for increased and stimulating student engagement.
(9) Provide a step-by-step guide on how the development of the videos was undertaken for upscaling and mapping across disciplines.

RESULTS AND DISCUSSION

A total of seven chemistry videos were created, as detailed in Table 1, with an engagement of ten separate Australian industries. In total, more than 15 industries were contacted for possible engagement. This required negotiation of copyright permissions with all of the industries as well as licenses to be purchased (see the Supporting Information for a summary of the copyright permissions). Five of the seven videos were released in semester 2, 2015, while the remaining two videos were released in semester 2, 2016. The topics for the videos were selected on the basis of the organic, physical, and bioinorganic topic areas that are taught in CHEM1239. Views of the videos created have also been tracked via YouTube (Table 1) and further championed and promoted by industry partners (Diabetes Australia).[39] The result of such industry engagement and endorsement has elevated the impact with 78% of the total views, a testament to the resource created.

The videos that were created were shown to the student cohort at the lectures to supplement the lecture content delivered. It was explained that the purpose of the short videos (typically about 3 min in length) was to showcase a real-life example of the topic area being studied together with an industry involvement so that students may understand the relevance of the topic to everyday life and also to their University degree. Directly after viewing the video, students were to partake in a voluntary quiz via Kahoot.it, which is a free game-based learning platform. Three simple questions pertaining to the video and theory content are released to the students via any device. Typically, students opt in using their mobile phones and they have 20 s to answer each of the three questions. After 20 s, the correct answer is provided to the students in a graphical format so that the entire class response can be viewed. The teacher is immediately able to provide clarification and further elaboration for the correct answer. This provides a fun and formative way to provide immediate and real-time feedback, which is often so difficult to achieve in large classes. Students have enjoyed such interactive, real-time quizzing as is evident in a number of the student comments.

A number of potential risks to successfully delivering this learning and teaching innovation were identified in the planning phase. To reduce these risks, appropriate treatment plans were developed:

(1) Ensure timely consultation with relevant industries to provide an industry focus.
(2) Arrange access to media and video production (e.g., professional photography, voice over, RMIT branding, and publication to YouTube).
(3) Obtain assistance with copyright permissions.
(4) Selection and supervision of a suitably qualified research assistant and selection of team.
(5) Identify whether ethics approval will be necessary.
(6) Identify and locate training and advice with implementing surveys and quizzes.
(7) Create video using off-the-shelf software (in this case via Adobe Premier CC).

Critical Success Indicators/Useage/Implementation

The learning design pattern has been implemented and evaluated in CHEM1239 (Chemistry for Life Sciences) at RMIT University over two years using simple quizzes and a survey created either through Google Drive or by using Kahoot.it.[38]

Views of the videos created have been tracked via YouTube (see Table 1) and also in Blackboard Learn, which is the current Learning Management System employed at RMIT University. The intention is to obtain feedback on the video content and student comprehension. This has been achieved in real-time at the lectures (on a voluntary and anonymous basis as required by the ethics application). Students have interacted via Kahoot.it, which provides a quiz and a survey via a game scenario. The survey was a series of ten questions aimed at getting student feedback on the videos. Responses in the CES issued by the University to the students at the end of the semester and the actual performance of the student cohort provide the final evidence to evaluate the success of the learning and teaching innovation (see Student Engagement section).

The videos created are directly relevant to a number of first-year undergraduate chemistry courses at RMIT University that incorporate students from the food science and nutrition, chemical engineering, applied science, biotechnology, and environmental science programs spanning across the School of Science as well as within the College of Science, Engineering and Health, some of which are online offerings through Open Universities Australia.

Student Engagement

The Course Experience Surveys (CES) that are issued to students toward the end of a teaching semester provide a direct measure of the teaching performance and student engagement at Australian Universities. In the CES survey, the Good Teaching Score (GTS) and Overall Satisfaction Index (OSI) are recorded for each teacher in a course. The 2015 CES data obtained following the release of five of the seven videos created reflected a strong student engagement with the content. These videos were released by lecturer 1 and 3 (see Figure 1) in 2015. For these lecturers, the GTS figure rose by 7% and 5%, respectively, while the OSI was essentially maintained in the years 2014 to 2015 following the release of the five videos related to the organic chemistry topics. In 2015, since only five videos (together with 1 Google and 4 Kahoot.it quizzes) were introduced in the organic chemistry unit of CHEM1239, the overall score achieved for the organic chemistry exam provided a means of looking at the student performance. There was a 10% increase in the score achieved for the organic chemistry exam from 2014 to 2015 (56% to 66%). The 2016 CES provides a clearer picture of the engagement since all seven videos and associated Kahoot.it quiz questions had been released to the students. In addition, in the 2016 CES for lecturer 1, the number of responses received from the students rose to 46% for as compared to a response of only 28% in the 2015 CES for the same lecturer, and importantly, the student

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J. Chem. Educ. XXXX, XXX, XXX−XXX

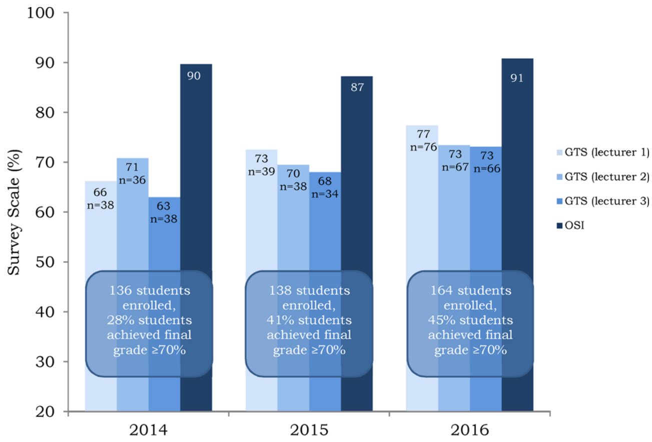

Figure 1. Course Experience Survey Results (CES) showing the Good Teaching Score (GTS) and Overall Satisfaction Index (OSI) for the three CHEM1239 teaching staff as well as the percentage of students achieving a result of >70% in their final grade. The number of CES responses to the survey is given by *n*, and the total number of students enrolled is also provided.

enrollment increased from 138 students in 2015 to 164 students in 2016. Student comments for 2015 and 2016 are presented below, while the GTS and OSI results for the years 2014−2016 for all three teaching academics show a significant increase in the GTS and also a rise in the OSI over these years (see Figure 1). The GTS rose by 11% for lecturer 1, 3% for lecturer 2, and by 10% for lecturer 3 from 2014 to 2016, while the OSI was essentially maintained in the years 2014 to 2016 following the release of all seven videos. The most significant difference was seen in the years 2015 and 2016 since the release of these videos and quizzes is that the percentage of students achieving >70% for their final grade in the course increased by 13−17% since 2014. This is a clear indication that students performed better and have improved their understanding of the chemistry content.

In analyzing the student responses to the Kahoot.it questions related to the videos (see Figure 2), it can be clearly seen that the student responses to the questions for Videos 1, 6, and 7 in 2016 were poor (up to 100% incorrect for one of the questions in Video 1 on the topic of stereochemistry: thalidomide). This provided an immediate opportunity for the teacher to engage with the students and correct them on why their response was incorrect. Importantly, this could be achieved in a relaxed environment and in an anonymous fashion. Student comments appreciated these aspects about the quizzes. Videos 6 and 7 were released for the first time in 2016 so there is no comparison for these responses. However, once again, this provided the teacher with the opportunity to engage and correct students and guide them in the understanding of the topic material. The responses in all of the other videos, which were shown in 2015 and 2016, were consistent between years.

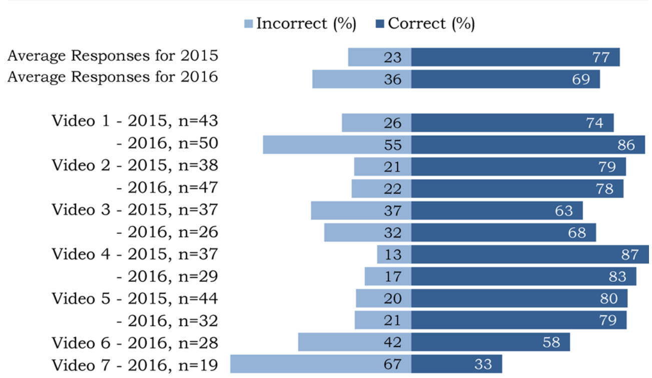

Figure 2. Student responses to the Kahoot.it questions for Videos 1−7 in 2015 and 2016 (note: videos 6 and 7 only released in 2016). For each video, there were three Kahoot.it questions with four possible answers from which to choose. Responses to these questions were averaged for each year. Student enrolment numbers were 138 in 2015 and 164 in 2016, and *n* is the number of student responses.

The student comments clearly illustrate student satisfaction with the videos. Through the CES in 2015, students from CHEM1239 were asked "What are the best aspects of this course?" Typical student comments were:

> *The videos and Kahoot.it quizzes.*
> *Having interactive lectures (quizzes) really help to keep people alert and better absorb information.*
> *Please continue the videos. They were interesting and had real world examples of the topics we were learning about.*
> *The lecturers always use the content we learn in the course and help us apply the knowledge to real-life situations, which gives the course a purpose.*
> *The online videos were very helpful.*
> *The use of the video quizzes was quite stimulating.*
> *The videos about the real-life scenarios that were shown in class.*
> *The videos were very helpful in relating the theory with real-life situations. Very well done!*
> *The videos were quite good because it let students know the applications and the use of studying chemistry, particularly in organic chemistry.*

In 2016, via the CES, CHEM1239 students offered these comments:

> *I personally like the videos and Kahoot games very much. Reminds us what we have learnt and makes sure we all understand the basic knowledge. It makes me realize what we are learning can really affect our future career; hence I have more motivation to learn chemistry. And it is fun!*
> *The videos were interesting though, and a quick quiz or two to make sure we're all following along correctly is helpful.*
> *The beauty of quizzes in this style (and also in PowerPoint clicker quizzes) is the anonymity; students and staff can get feedback without any embarrassment.*
> *She shows us relative videos, introduce us the class online quiz, Kahoot, which is really fun. And she makes us feel engaged to this course and motivated to learn this course better.*
> *Also, being able to test our knowledge and get immediate feedback by doing Kahoot.*
> *The videos and Kahoot quizzes were great also.*
> *The variety of learning methods used to enhance the student learning experience.*
> *There were lots of visual (videos, images, structures) used during lectures which helped a lot.*
> *Videos and test games help me to understand course contents and evaluate my understanding of the contents.*
> *Having printed notes and interactive lectures (quizzes) really help to keep people alert and better absorb information.*

The CES results together with the level of the final grade achievement are a testimony to enhanced student engagement (see Figure 1). As a final measure of what the students thought about the seven videos, a Kahoot.it survey was created in which

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J. Chem. Educ. XXXX, XXX, XXX−XXX

ten questions were asked. (See the Supporting Information for complete questions.) The responses are given in Figure 3.

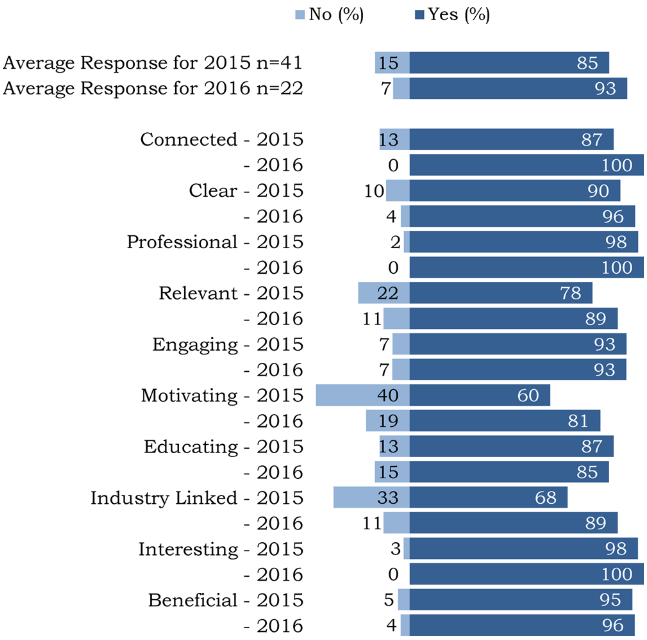

Figure 3. Student responses to the Kahoot.it survey for what they thought about Videos 1–7 (note: videos 6 and 7 only released in 2016). Student enrolment numbers were 138 in 2015 and 164 in 2016, where *n* represents the number of student responses.

Overall student responses were consistent across 2015 and 2016 with 88% and 89% of students reflecting a positive experience. Responses trended the lowest for relevant (78–89%), motivating (60–81%), and linked to Industry (68–89%). The top responses were that the videos were: Connected, Professional, Interesting, Clear, Beneficial, and Engaging. The positive feedback received from students indicated that they achieved their fundamental aim of being relevant, motivating and engaging, while still being professional.

Finally, the overall pass rates for the CHEM1239 course for the years 2014–2016 have steadily increased from 85% to 88% over the years 2014 to 2016. The use of the videos, which have an Australian industry connection, showcases the real-life relevance of chemistry for the current student cohort and presents potential future employers in relevant fields of study.

The videos, together with the use of Kahoot.it for the quizzes and survey, provide a stimulating student experience by engaging them immediately with the course content in a real-life example with Australian industry relevance. Students participate anonymously in the quizzes and survey using any device, and the teacher obtains a real-time response, which enables immediate engagement and revision of content.

CONCLUSIONS

The use of the videos, which have an Australian industry connection, showcases the real-life relevance of chemistry for the current student cohort and presents potential future employers in relevant fields of study. The videos, together with the use of Kahoot.it for the quizzes and survey, provide a stimulating student experience by engaging them immediately with the course content. They illustrate a real-life example of chemistry in action with a relevant Australian industry engagement. Students participate in quizzes/survey using any mobile device by giving the teacher a real-time response, which enables formative feedback.

ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available on the ACS Publications website at DOI: 10.1021/acs.jchemed.7b00063.

Technology and education resources utilized to create the videos; Kahoot.it quiz questions for each video; survey questions; copyright permissions; example of storyboard (PDF)

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Notes

The authors declare no competing financial interest.

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J. Chem. Educ. XXXX, XXX, XXX−XXX