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Animating student engagement: The impacts of cartoon instructional videos on learning experience

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In the modern age of education, students increasingly demand engaging, customized multimedia content. Animation constitutes a powerful pedagogical tool by combining audio messages with tailored visual cues and graphics, to serve the dual functions of explaining complex concepts and engaging student interest in the learning process. This study explores the use of a series of animated videos to teach advanced accounting at an Australian university. Based on survey responses from 254 undergraduate students over two semesters, we provide evidence of the specific avenues through which animated instructional videos enhance students' learning experience, including increased engagement and interest, improved understanding and greater flexibility in self-directed learning. Additionally, character design, voice acting and dialogues in animated videos are found vital to improving student engagement. Further, this study offers novel insights into how students from various demographic groups can derive different benefits from the animations. These findings deepen our existing understanding of the pedagogical advantages of animated instructional videos and offer valuable guidance to enable future educators to harness the power of animation technologies to produce effective teaching resources.

Keywords: animations; animated teaching videos; multimedia resources; student engagement

Introduction

A key challenge shared by educators is how to engage students while delivering content of a technical, complex, difficult and sometimes tedious nature. Students in advanced-level accounting courses often struggle to maintain their interest in the course materials, which involve abstract concepts and convoluted calculations. Technological advancements offer exciting new opportunities to educators to provide more engaging and effective teaching resources (Gerjets and Hesse 2004; Voithofer 2005). They also bring an increasing demand amongst modern students for engaging, customized multimedia resources to assist their learning (Gorissen, Van Bruggen, and Jochems 2012; Kaufmann and Mohan 2009). The availability of Web 2.0 applications has fundamentally changed the way in which information is disseminated in education (Crook 2012; Greenhow, Robelia, and Hughes 2009; Roschelle and Pea 1999). Specifically,

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there is an increasing trend amongst universities to provide lecture recordings online (Gorissen, Van Bruggen, and Jochems 2012) and incorporate video resources into their curricula (Kim *et al.* 2014; Tan and Pearce 2011). Further, as a result of the development of animation technologies over the last decade, the creation of animated videos is no longer a complex feat reserved for the likes of Disney studio artists but is widely accessible to educators and students (Furlong and Davies 2012).

In response to these challenges and opportunities, educators at an Australian university developed a series of animated instructional videos designed to explain complex, technical accounting and business principles in a final-year undergraduate course. As a part of this project, implemented over two semesters, a series of nine animated videos were produced to cover all major topics in the syllabus. The videos, ranging from 3 to 5 minutes in length, provide an overview of the fundamental principles in each topic and explain and illustrate the technical concepts with the aid of graphics and/or real-world examples. This study investigates the impacts of these animated teaching videos on students' learning process.

Using survey responses from 254 students from two cohorts over different semesters, this study investigates the specific avenues through which animated videos affect student learning, as measured by the level of interest, engagement, enjoyment and ease of access experienced by the students. In addition, we examine the roles of student demographic characteristics, including age and gender, in determining how students utilize the animated instructional videos.

The findings of this study seek to contribute to the existing literature in three important ways. This study is the first to utilize a series of animations as instructional videos in higher education, by combining the dual functions of (1) explaining complex technical concepts (e.g. Kelly and Jones 2007; Lowe 2003; Nelson *et al.* 2017) and (2) providing engaging context and real-world applications of the principles taught (e.g. Adam *et al.* 2017; Bassford *et al.* 2016; Mather 2015). This study adds to the rapidly growing literature on the use of multimedia resources in education (Anderson *et al.* 2018; Clark, Tanner-Smith, and Killingsworth 2016; Mayer and Anderson 1992; Takacs, Swart, and Bus 2015; Theobald 2017). Secondly, drawing on cognitive theory (Mayer 1999) and John Dewey's pragmatist conception of learning as a social activity (Dewey 1916; Kivinen, Piiroinen, and Saikkonen 2016), this study provides novel evidence of the multifaceted pedagogical benefits of animated instructional videos and their impacts on student learning. Thirdly, we contribute to the literature that examines students' individual idiosyncrasies in influencing their learning experience (Johnson *et al.* 2013; Roschelle *et al.* 2010; Rosenberg-Kima *et al.* 2010). We explore the impacts of student demographic characteristics (including age and gender) on the relationship between the use of animations and learning outcomes. The findings from this study also have significant practical implications, enabling other educators to better utilize animation-production technology as a powerful learning and teaching tool.

Literature review and contribution

Teaching videos

'An age of pictures dictates the use of pictures in class' wrote Richard Spencer nearly a century ago (Spencer 1938). Since then, the rise of the digital new media has overtaken the print media (Voithofer 2005). The rapid development of Web 2.0 applications has revolutionized the world of learning and teaching (Crook 2012; Greenhow, Robelia, and Hughes 2009; Roschelle and Pea 1999). Visual, audio and video aids constitute an increasingly indispensable component of modern education (Friesen 2011).

Prior researchers have examined the pedagogical benefits of a variety of multimedia teaching resources, including contextual imagery (Baron 2016), audio–visual materials (Kinder 1942; Svenson and Sheats 1950; Wendt and Butts 1962), instructional videos (Clark, Tanner-Smith, and Killingsworth 2016; Homer, Plass, and Blake 2008; Sun and Cheng 2007) and games (e.g. Abdul Jabbar and Felicia 2015; Clark, Tanner-Smith, and Killingsworth 2016; Squire 2006). In particular, multimedia videos have been used for a variety of purposes in higher education, including delivering instructions (Chen *et al.* 2014; McLaughlin *et al.* 2014; Tan and Pearce 2011), sharing viewpoints and discussions (Goldman 2004; Kim *et al.* 2014; Tan and Pearce 2011), providing peer feedback and self-reflection (Jordan 2012) and facilitating industry placements (Taylor 2012).

An increasing number of universities provide lecture recordings or online videos to accompany face-to-face teaching (Gorissen, Van Bruggen, and Jochems 2012; Tan and Pearce 2011). Videos with on-screen instructors are generally considered superior to voice-over–type recordings (Chen and Wu 2015; Lee, Hsiao, and Ho 2014; Lyons, Reysen, and Pierce 2012), as visual cues and social presence are important components of teaching videos (Adams *et al.* 2014; Lee, Hsiao, and Ho 2014; Lyons, Reysen, and Pierce 2012). In the specific context of accounting education, prior researchers have examined the use of multimedia resources (Chan *et al.* 2016; Johnson, Phillips, and Chase 2009; Richardson and Louwers 2010), including instructional videos (Daigle, Hayes, and Morris 2014; Holtzblatt and Tschakert 2011; Lento 2017). Lento (2017) finds that voice-over videos facilitate the flipped classroom and help accounting students engage in active learning. Daigle, Hayes, and Morris (2014) use video clips of interviews from daytime television shows to teach accounting students about occupational fraud, documenting improved understanding and knowledge. Even though digital video technologies offer significant new potential to enhance accounting education (Holtzblatt and Tschakert 2011), some researchers observe that accounting academics have not fully embraced the opportunities offered by new technologies (Pincus *et al.* 2017; Rebele and St. Pierre 2015; Watty, McKay, and Ngo 2016).

The existing literature documents several advantages associated with multimedia teaching videos, including increased student engagement (Loong and Herbert 2012; Roschelle *et al.* 2010; Tan and Pearce 2011), improved ability to apply the knowledge in problem-solving (Ellis 2004; Mayer 1999) and flexibility to learn at any time and location (Gorissen, Van Bruggen, and Jochems 2012) and at each student's own pace (Chen *et al.* 2014; Eysink *et al.* 2009). Nonetheless, the literature also reveals potential downsides of multimedia teaching resources. Firstly, the high costs of production and development limit their accessibility to educators (Sun and Cheng 2007). Secondly, extraneous details in the animations can distract students from the relevant messages (Homer, Plass, and Blake 2008; Lowe 1999). Thirdly, video viewing is found to be an inadequate substitute for class participation and discussions (Ronchetti 2010).

Animations in higher education

Animated videos constitute a subset of multimedia resources. Animations are an important component of entertainment consumed by children and young adults, which serve educational functions (Anderson *et al.* 2018; Sproull 1973; Theobald 2017) and influence popular culture (Trifonas 2001). Animated graphics are found to improve learning in various age groups, ranging from young children (Takacs, Swart, and Bus 2015) to high-school students (Loong and Herbert 2012; Roschelle *et al.* 2010).

Despite the prevalence of cartoon programs, there remains limited research on the use of animations as instructional media in higher education (e.g. Adam *et al.* 2017; Kelly and Jones 2007; Mather 2015; Tasker and Dalton 2008). In the small but growing body of extant literature, animations have been used for two main purposes: (1) explaining basic concepts or (2) providing real-world context and application of existing knowledge. Firstly, science educators have used black and white animated graphics to illustrate molecular-level movements (Kelly and Jones 2007; Sanger, Brecheisen, and Hynek 2001; Tasker and Dalton 2008; Nelson *et al.* 2017). For example, Nelson *et al.* (2017) use animated simulations to explain movements of electrons during the process of diffusion. Similarly, Kelly and Jones (2007) use animated illustrations of molecular structure and dynamics in chemistry teaching, which students report to be useful.

In contrast, the second use of animations is to provide real-world (or simulated) context and examples of technical concepts and principles to enrich the learning process. For example, Adam *et al.* (2017) develop a series of 36 animated videos at the Stanford School of Medicine in collaboration with four other US medical schools. The videos present stories from fictitious patients to provide real-world application of the technical content taught in medical courses. Additionally, animations can be used to enrich students' learning tasks and assessments. For example, Bassford *et al.* (2016) incorporate a realistic, interactive crime scene into science, technology, engineering and mathematics (STEM) courses to engage students in interactive learning. Similarly, in teaching computer programming, Mather (2015) uses an animated virtual landscape in which students interact with robot subjects to complete programming tasks.

However, this body of research has produced inconclusive and contradictory evidence on how animations affect students' learning outcomes. For example, while some researchers find that animated illustrations or assessments improve student understanding in experimental settings (Lowe 2003; Mather 2015; Sanger, Brecheisen, and Hynek 2001), others show that animated simulations can indeed generate or reinforce misconceptions in science learning (Kelly and Jones 2007; Nelson *et al.* 2017; Lowe 2003). Lowe (2003) concludes that the effectiveness of animations depends largely on their design.

Importantly, prior studies have largely focused on student learning outcomes, measured by their level of understanding, as a criterion for the success of the animated resources (e.g. Kelly and Jones 2007; Nelson *et al.* 2017; Sanger, Brecheisen, and Hynek 2001). However, student understanding only captures one aspect of their overall learning experience, namely the outcome. We posit that for students to have a positive learning experience, it matters not only how much they learn, but also how interesting, enjoyable and easy they find the process of learning. Limited prior research has been conducted into these measures of the student learning experience associated with animated resources. We fill this gap in the literature by incorporating these aspects into our investigation.

Distinction between comics, moving graphics and cartoon animations

The definition of 'animations' or 'cartoons' remains ambiguous in the literature. An important distinction must be drawn between cartoon animations versus moving graphics, which are colloquially referred to as 'animations' (following the use of the term by Microsoft's PowerPoint software). For example, Chiou, Tien, and Lee (2015) examine PowerPoint presentation–style animations that consist of still graphics appearing and moving across the screen. Indeed, prior researchers use the term 'animation' or 'cartoon' to describe a variety of different multimedia resources, including the following:

- Three-dimensional still backgrounds (Mather 2015)
- 'Concept cartoons' used in science education, referring to illustrative drawings similar to comic strips (Keogh and Naylor 1999; Warwick and Stephenson 2002)
- Static graphics with simple movements (Ellis 2004)
- Black and white or grayscale illustrations of molecular movements, some with no sound effect (Kelly and Jones 2007; Mayer 1999; Nelson *et al.* 2017)
- Avatars (animated characters) that appear in educational videos (Cantley, Prendergast, and Schlindwein 2017; Johnson *et al.* 2013; Lee, Hsiao, and Ho 2014; Rosenberg-Kima *et al.* 2010; Wouters, Paas, and Van Merriënboer 2008).

In this study, we refer to animations to mean cartoon-style videos with a basic storyline, characters, and dialogues or voiceovers, in which the graphics move in synchrony with the accompanying voice acting and sound effects (e.g. a character's mouth opens when speaking). This distinction is important, because our cartoon animations can deliver a number of benefits beyond those of simple moving graphics, 3D still images or avatars. Firstly, compared with static images with added movements, cartoon animations enable educators to incorporate more sophisticated visual effects to demonstrate and explain technical, abstract concepts. Secondly, in contrast to 3D still images or black and white illustrations, scripting and voice acting can play an important role in cartoon animations, by introducing storyline and banter into the videos to engage students' attention and interest. Finally, by presenting recurring characters, animated dialogues and simulated real-world sets and backgrounds, our animation series allows students to immerse themselves into the world created by their educators, which further enhances student interest in the course materials.

Gap in existing literature and contribution

This paper is the first to empirically examine the use of cartoon animations to serve the dual pedagogical purposes of (1) explaining new complex technical concepts and (2) engaging student interest in the learning process. We document novel evidence of the impacts of cartoon animations on university students' learning experience. Our findings provide significant contributions to the existing literature in a number of ways.

Firstly, we combine two major functions of animations: explaining new complex concepts to students (Kelly and Jones 2007; Lowe 2003; Nelson *et al.* 2017) and engaging students' interest with multimedia examples, anecdotes and real-world context (Adam *et al.* 2017; Bassford *et al.* 2016; Mather 2015). Unlike the animations developed by Adam *et al.* (2017), our animations are designed to convey new knowledge to students, who are exposed to these concepts for the first time, rather than to reinforce or apply existing knowledge with (simulated) real-world anecdotes or interactive tasks (Bassford *et al.* 2016; Mather 2015). Further, unlike the black and white animations for science teaching that illustrate molecular movements (e.g. Kelly and Jones 2007; Mayer 1999; Nelson *et al.* 2017), our animations serve the additional function of providing real-world examples and context while engaging students with storylines and dialogues. Our evidence demonstrates that both engaging student interest *and* enhancing their understanding of the subject matter constitute important avenues for animated videos to improve students' overall learning experience.

Secondly, this is one of the first studies to use cartoon programme–style animations, complete with characters, dialogues and basic storylines, as instructional tools in higher education. This enables us to investigate which aspect of the design of an animated video contributes most significantly to engaging students' interest and attention. We find that character design, dialogue scripting and voice acting provide the most potent hooks to engage learner attention and enhance viewer enjoyability. These novel findings inform future educators on the optimal design and production process of animated teaching resources.

Thirdly, we further explore the role of students' individual and demographic idiosyncrasies, such as age and gender, and how they influence the students' interactions with the animated videos and the benefits derived from them. Prior studies show that student demographic characteristics, such as gender and age, are significant in determining accounting students' approaches to learning (Apostolou *et al.* 2017; Duff 1999). However, no prior studies have investigated whether and how these demographic characteristics affect the students' learning experience when utilizing animated instructional videos, as measured by the level of interest, enjoyability, ease of understanding and ease of access. The findings in our study provide important insights into how students in various demographic groups derive different benefits from animated teaching resources. Finally, unlike prior studies that report student survey responses (Adam *et al.* 2017; Mather 2015), we also conduct regression analyses to document findings supported by statistical evidence.

Theories and predictions

We expect animated instructional videos to enhance students' learning experience in two significant ways. Firstly, under Dewey's pragmatic view of learning, the learning process is regarded as an inherently social activity derived from human interactions (Chee 2011; Dewey 1916; Kivinen, Piiroinen, and Saikkonen 2016). Consistent with this view, prior studies find that the on-screen appearance of instructors or avatars serves an important social function to engage students (Adams *et al.* 2014; Cantley, Prendergast, and Schlindwein 2017). Specifically, Wouters, Paas, and Van Merriënboer (2008, p. 667) document that '[a]nimated [avatars] can give support to the learner and stimulate the learner to invest effort to understand the model performance depicted in the animation'. Accordingly, we hypothesize that the cartoon characters, dialogues and simulated real-world settings in the animations will enhance students' learning experience by increasing the level of engagement, interest and enjoyability during the learning process.

Secondly, we expect the visual aids and illustrations to help students attain a better understanding of the concepts and principles explained in the videos. According to cognitive theory, more effective learning occurs when a learner experiences reduced cognitive load during a video viewing, because of the constraint on human working memory capacity (Homer, Plass, and Blake 2008; Mayer 1999). Some debates persist over whether the presence of additional visual content increases or decreases viewers' cognitive load (Chen and Wu 2015; Homer, Plass, and Blake 2008; Wouters, Paas, and Van Merriënboer 2008), though more recent evidence supports the latter view (Chen and Wu 2015). Accordingly, under cognitive theory, we hypothesize that animated videos will improve the learning outcomes of the viewers and help them attain better understanding.

Method

Study setting

To test these theoretical expectations, we conducted a case study in the context of a compulsory undergraduate final-year accounting course at an Australian university. The course is delivered to over 200 students each semester, who specialize in accountancy as a part of their bachelor degree in business. Some students have dual specializations in combination with corporate finance, management, marketing or international business. A small portion of students undertake their accounting studies in combination with another degree (such as the bachelor of laws, which is the most common). The cohorts of students comprise a balanced mix of male and female students. Given that this is a third-year course, the ages of the students typically range from 20 to 25, consistent with expectation. More specifically, over 84% of the survey respondents reported being between 20 and 23 years of age. Approximately 10% of the survey respondents identified themselves as aged 24–25. Less than 5% of the students reported being 26 or older, and less than 1% 19 or younger.

This study involved the production of a series of animated videos to teach complex concepts and methods of advanced accounting. The animated videos are provided to students as a part of the pre-lecture videos for each topic. Similar to prior studies (e.g. McLaughlin *et al.* 2014), the animations are distributed on the course online learning platform (Canvas) *prior* to students attending face-to-face lectures, in order to facilitate a flipped classroom approach (Chen *et al.* 2014; Kim *et al.* 2014). After viewing the videos, students complete weekly online quizzes (consisting of four to six questions), which form a part of their summative assessment.

This advanced-level accounting course is characterized by complex, difficult and highly technical content. In past course evaluations, students often commented on the 'complexity of the topics', which were 'difficult to grasp'. One challenge in helping students gain a thorough understanding of the course materials lies in the *abstract* nature of the convoluted accounting principles, which are difficult to visualize. In addition, given the abundance of technical details and complicated calculations covered in the curriculum, another key challenge is how to engage and motivate students to become interested in the course materials.

Animated teaching videos

In response to these challenges, a series of nine animated cartoon videos were developed and produced, through careful pedagogical design, and deployed over two semesters in the 2017 and 2018 academic years. The animated series covers all major topics in the course. In the syllabus, the animated videos constitute the first teaching resource that students access when studying each topic. The videos are aimed at providing an introductory overview of the topic, explaining the fundamental accounting or business principles and presenting a 'hook' to engage students' interest through

Figure 1. Screenshots of animated videos.

real-world examples or story scenarios. Figure 1 provides several screenshots from the animation series. The animations are designed to serve two overarching objectives: the first objective encompasses engaging student attention, enhancing interest in the materials and improving overall enjoyability of the learning process; the second aim is providing visual stimuli to illustrate complex technical concepts to help students achieve better understanding.

Animation technology and production process

The advancement of animation technologies makes the process of creating customized animated videos more accessible to educators. The production process typically involves the following steps. Firstly, the instructor prepares a script and storyboard drawings in accordance with pedagogical needs, and the video producer creates cartoon characters (using Adobe's Character Animator and Photoshop), animated sets, props and other visual assets from a combination of hand-drawings, computer-generated objects and photographs. Secondly, voice acting is recorded using Character Animator, a software that uses facial-mapping and lip-syncing technology to map a cartoon character's facial expressions following those of the actor. Voice-overs are recorded separately. Thirdly, the producer edits the visual footage, graphics, background and foregrounds to create a seamless three-dimensional sequence, before adding audio recordings, sound effects, music and captions. Finally, the completed video is exported as an MP4 file and reviewed by the instructor for continuity and accuracy, before it is posted on the course's online learning platform.

Survey data collection

Two surveys were administered to two different cohorts of students in 2017 and 2018. In each semester, all students participating in this advanced accounting course were

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invited to fill out the survey, which was administered on the Canvas course website. A total of 109 valid responses were received in the first semester, and 145 were received in the second semester.

The survey instruments were designed to explore students' experience of engaging with the animated videos. As a part of the survey validation, we conducted a principal components analysis (PCA) to generate the factor loadings for each variable corresponding to each question in the survey instrument. The factor loadings for all questions included in the survey instrument exceeded the validity threshold of 0.40 in the literature (Stevens 1992) (some argue that a lower threshold of 0.35 should have been used given the sample size of 250 [Hair *et al.* 1998, p. 112]). These results from the PCA supported the validity of the survey instrument. The surveys consisted of three parts: (1) Likert-scale questions relating to different pedagogical features of the animated videos, (2) a free-comment section in response to the question 'what are the best aspects of the animated (cartoon) videos?' and (3) questions about students' individual and demographic information. The survey questions are detailed in Appendix A. The survey administered in the first semester (2017) consisted of fewer Likert questions. Based on the free-response comments provided by the respondents in the first-semester survey, we were able to develop more targeted and detailed Likert-scale questions in the second survey administered in 2018, in order to obtain quantitative evidence to corroborate the qualitative findings from the written free-response comments.

Empirical results

In this section we discuss and analyse the survey results. We first discuss the free-response comments from students, which shed light on the specific aspects of the learning experience that are improved by animated instructional videos. We then provide descriptive statistics relating to the Likert-scale responses. Next, we present the empirical results from a series of regression analyses to provide further insights into the pedagogical benefits of animated videos as a learning tool.

Survey results: Free-response comments

Amongst the 254 survey respondents over two semesters, 173 students (68%) provided written comments in response to the question 'what are the best aspects of the animated (cartoon) videos?'. The overarching themes identified by students in relation to the best aspects of the animation videos include interesting, engaging, easy (to understand), different, and entertaining. Of 254 survey participants, only 4 students (<2%) provided negative comments about the animated videos (e.g. 'I don't care for them'); the remaining comments were positive.

Upon careful review of these written responses, we further grouped the comments into three main categories in accordance with the overarching themes, including (1) comments relating to increased interest, enjoyability and engagement (which measures student attention); (2) comments relating to how animations assist students' understanding, for example, through simplifying concepts or providing visual illustrations; and (3) comments relating to the attraction of animations as something 'different' or a change from conventional teaching materials. The comments from students enabled us to identify a number of recurring themes relating to the animations' impacts on the learning process. This knowledge in turn allowed us to develop and refine our Likert-scale questions in the second survey to include more targeted questions about the specific pedagogical benefits of the animated videos.

Descriptive statistics

Animated videos and student learning experience

Table 1 reports the student responses to the Likert-scale questions. A total of 254 responses were received over two semesters. Firstly, the survey results provide an overview of the usefulness of the animated videos to students' learning. In response to Question 11 ('overall, I find the animated (cartoon) videos helpful to my learning'), 83% of the survey participants either strongly agreed or agreed with this statement.

In addition, the Likert-scale questions (Q1–Q10) are designed to provide further insights into the *specific* avenues through which the animations enhance students' learning experience, including (1) increasing interest, enjoyability and engagement; (2) improving understanding of the technical content; (3) providing flexibility and self-directed learning; and (4) constituting a refreshing change from conventional teaching materials.

Firstly, a vast majority of the survey respondents found the animated videos interesting (Q1: 77% agree/strongly agree), enjoyable (Q2: 79%) and helpful to their concentration (Q3: 76%). Consistently, 72% of the survey participants strongly agreed or agreed that '[t]he animated (cartoon) videos [stimulated] my interest in the course materials' (Q10). Secondly, 79% of the participants agreed or strongly agreed that the animations were 'helpful in assisting [their] understanding of the key concepts' (Q4). Similarly, 81% of the participants concurred that the videos '[assisted their] learning by simplifying complex and technical concepts' (Q5), and 80% found that the 'visual stimuli and graphic illustrations of abstract technical concepts' enhanced their learning (Q6). Thirdly, a vast majority of survey participants valued the flexibility (Q7: 79% agree/strongly agree) and self-paced learning (Q8: 78% agree/strongly agree) offered by the animated videos. Finally, 86% of the survey participants agreed or strongly agreed that the animations provided 'a refreshing change from regular teaching materials' (Q9). These descriptive statistics provide preliminary support for the various pedagogical benefits associated with animated videos; however, in the following sections, we will provide further statistical evidence on the role of each of these factors by conducting regression analyses.

Aspects of animation design and student engagement

The effectiveness of animated teaching resources depends largely on their designs (Lowe 2003). Question 16 of the survey was designed to gauge which specific aspects of the animated videos were most effective in achieving the pedagogical objective of engaging students. The question asked: 'what do you find to be the most memorable aspect(s) of the animated videos? (Please tick as many as relevant)', while providing a series of options for multiple selection, including (1) voice acting, (2) character design, (3) dialogues, (4) visual cues and graphics, (5) background or set design and (6) music and scoring. Based on student responses, we computed six binary variables. Each variable was coded 1 if the student had selected the corresponding option and 0 otherwise. As reported in Table 1, character design constituted the most popular

Table 1. Descriptive statistics of survey responses.

Q#	Variable	Survey question	Responses	Strongly disagree		Disagree		Undecided		Agree		Strongly agree	
1	interesting	I find the animated (cartoon) videos interesting to watch.	251	6	2%	14	6%	37	15%	116	46%	78	31%
2	enjoy	I enjoy watching the animated (cartoon) videos.	145	1	1%	9	6%	21	14%	55	38%	59	41%
3	engage	The animated (cartoon) videos engage my attention and help me concentrate.	142	1	1%	8	6%	25	18%	64	45%	44	31%
4	understand	I find the animated (cartoon) videos helpful in assisting my understanding of the key concepts.	251	6	2%	13	5%	34	14%	120	48%	78	31%
5	simplify	The animated (cartoon) videos assist my learning by simplifying complex and technical concepts.	145	1	1%	9	6%	18	12%	78	54%	39	27%
6	visual	The animated (cartoon) videos enhance my understanding by providing visual stimuli and graphic illustrations of abstract technical concepts.	144	1	1%	10	7%	18	13%	71	49%	44	31%
7	flexible	The animated (cartoon) videos provide more flexibility to accommodate my busy schedule (including work commitments).	145	1	1%	11	8%	19	13%	61	42%	53	37%
8	selfpace	The animated (cartoon) videos enable me to achieve better outcomes through self-paced learning (e.g. pause, rewind, repeat certain sections).	145	1	1%	10	7%	21	14%	60	41%	53	37%
9	refreshing	The animated (cartoon) videos present a refreshing change from regular teaching materials.	143	0	0%	7	5%	14	10%	64	45%	58	41%
10	stimulate	The animated (cartoon) videos stimulate my interest in the course materials.	251	4	2%	21	8%	44	18%	109	43%	73	29%

Table 1. (*Continued*)

Q#	Variable	Survey question	Responses	Strongly disagree		Disagree		Undecided		Agree		Strongly agree	
11	animation_overall	Overall, I find the animated (cartoon) videos helpful to my learning.	251	4	2%	11	4%	27	11%	136	54%	73	29%
12	more_cartoon	I would like to see more animated (cartoon) videos in this course.	107	4	4%	12	11%	22	21%	48	45%	21	20%
13	cartoon_view	How much of the animated (cartoon) videos have you watched? (%)	147	9	6%	8	5%	9	6%	24	16%	97	66%
14	lecture_attend	How often do you attend lectures in person? (never – always)	254	16	6%	25	10%	58	23%	49	19%	106	42%
18	age	Your age	144	1	1%	59	41%	62	43%	15	10%	7	5%
19	cartoon_child	How much cartoon/animated programs did you watch in your childhood?	142	2	1%	3	2%	25	18%	61	43%	51	36%
29	cartoon_enjoy	How much do you enjoy cartoon and animated programs in general?	145	1	1%	8	6%	17	12%	67	46%	52	36%
				No								**Yes**	
16a	voice_acting	What do you find to be the most memorable	144	No: 88	61%			---				Yes: 56	39%
16b	character_design	aspect(s) of the animated videos? (Please tick	144	No: 66	46%			---				Yes: 78	54%
16c	dialogues	as many as relevant): voice acting, cartoon	144	No: 91	63%			---				Yes: 53	37%
16d	visual_cues	character design, dialogues, visual cues and	144	No: 71	49%			---				Yes: 73	51%
16e	background_set	graphics, background/set design, music and	144	No: 116	81%			---				Yes: 28	19%
16f	music_scoring	scoring.	144	No: 128	89%			---				Yes: 16	11%
17	gender	Your gender	141	M: 53	38%			---				F: 88	62%
18	age_d	Your age (median – split)	144	<22: 60	42%			---				≥22: 84	58%

aspect of the animation design, with 54% of the survey respondents selecting this option, followed by visual cues and graphics (51%), voice acting (39%), dialogues (37%), background or set design (19%) and music and scoring (11%).

Student demographic characteristics and idiosyncrasies

Moreover, the survey gathered information about the idiosyncratic characteristics of the survey participants, including demographic information such as age and gender, and students' general attitudes towards cartoons outside the classroom. For example, 62% of the survey participants were female and 38% male; 58% of the students were 22 years of age or older, and 42% were 21 or younger. In response to Question 19, 'How much cartoon/animated programs did you watch in your childhood?', 36% reported watching very frequently, 43% often and 18% sometimes, whereas only 2% reported watching occasionally and 1% rarely. We included these questions because prior research evidence shows that leisure activities involving multimedia content can affect its effectiveness for educational purposes (Cilesiz 2009) and impact on students' learning outcomes (Williams *et al.* 1982).

Statistical models

Animations and student learning experience

In this study, we employed the following regression models to analyse the survey data. We ran the ordinary least squares models specified in Equations (1) and (2). As robustness tests, we re-estimated the key equations in this study using Tobit regressions and Poisson regressions, in turn. In the untabulated results generated from these additional analyses, the estimated coefficients and statistical significance of the key independent variables remained substantively similar to those reported in the next section. These additional analyses provided further support for the findings in this study.

$$\begin{aligned} Animation\_overall_j = {} & \alpha + \beta_1 interesting_j \mid enjoy_j \mid engage_j + \\ & \beta_2 understand_j \mid simplify_j \mid visual_j + \beta_3 flexible_j \mid selfpace_j + \beta_4\, refreshing_j + \\ & \beta_5\, animation\_view_j + \beta_6\, lecture\_attend_j + \beta_7\, cartoon\_child_j + \\ & \beta_8\, cartoon\_enjoy_j + \beta_9\, age_j + \beta_{10}\, gender_j + \varepsilon_{it} \end{aligned} \quad (1)$$

$$\begin{aligned} Stimulate_j = {} & \alpha + \beta_1 interesting_j \mid enjoy_j \mid engage_j + \\ & \beta_2 understand_j \mid simplify_j \mid visual_j\, \beta_3 flexible_j \mid selfpace_j + \beta_4\, refreshing_j + \\ & \beta_5\, animation\_view_j + \beta_6\, lecture\_attend_j + \beta_7\, cartoon\_child_j + \\ & \beta_8\, cartoon\_enjoy_j + \beta_9\, age_j + \beta_{10}\, gender_j + \varepsilon_{it} \end{aligned} \quad (2)$$

We assumed that each observation in the analysis (representing each individual student's survey responses) was independent from other observations, as there was no theoretical or empirical evidence to suggest that students might collaborate on completing the survey or plagiarize each other's survey responses.

The dependent variable, $animation\_overall_j$, represents the overall usefulness of the animation videos to student learning (Q11). In addition, we also ran Equation (2) by employing an alternative dependent variable, $stimulate_j$, which captures the extent to which the animated videos stimulated students' interest in the course materials (Q10). Each independent variable corresponds to one of the survey questions (Q1–Q9), which explore specific avenues through which animations can impact on the learning process. We grouped the variables into four broad categories: (1) engaging student interest and improving enjoyability of learning (as captured by the variables $interesting_j$, $enjoy_j$ and $engage_j$); (2) helping students achieve better understanding by simplifying technical content and providing visual illustrations ($understand_j$, $simplify_j$ and $visual_j$); (3) providing flexibility and facilitating self-paced learning ($flexible_j$ and $selfpace_j$); and (4) offering a refreshing change from the format of conventional teaching material ($refreshing_j$).

Because of the high multicollinearity amongst variables in the same category (e.g. students who found the videos *interesting* were also likely to find them *enjoyable*), we ran a series of regression analyses by only including one variable at a time from each category of explanatory variables, while excluding any explanatory variable with a Pearson correlation coefficient of more than 70%. In addition, we report that the variance inflation factor for each regression included in this study was below 7, indicating that multicollinearity is not a significant concern.

Finally, we included the following control variables in the regression models: the amount of animated teaching videos viewed by the student ($animation\_view_j$), the students' lecture attendance ($lecture\_attend_j$), the amount of (non-educational) cartoon programmes the student watched as a child ($cartoon\_child_j$), the student's affinity towards cartoons in general ($cartoon\_enjoy_j$) and the student's age (age_j) and gender ($gender_j$).

Aspects of animation design and student engagement

We posit that the usefulness of the animated videos was directly related to the extent to which the animations can engage students. In this section, we explore the specific elements of the animation design that are most important to increasing student interest, enjoyability and engagement. We ran the following two-stage regression models.

Stage 1

$$interesting_j \mid enjoy_j \mid engage_j = \alpha + \beta_1\, voice\_acting_j + \beta_2\, character\_desion_j + \beta_3\, dialogues_j + \beta_4\, visual\_cues_j + \beta_5\, background\_set_j + \beta_6\, music\_scoring_j + \varepsilon_{it} \quad (3)$$

Stage 2

$$Cartoon\_overall_j = \alpha + \beta_1\, interesting\_p_j \mid enjoy\_p_j \mid engage\_p_j + \beta_2\, cartoon\_child_j + \beta_3\, cartoon\_enjoy_j + \beta_4\, age_j + \beta_5\, gender_j + \varepsilon_{it} \quad (4)$$

In the first-stage regression in Equation (3), we used a series of independent variables to capture various aspects of the animation design, including voice acting, character design, dialogues, visual cues and graphics, background and set design, and music and scoring. The three alternative dependent variables ($interesting_j$, $enjoy_j$ and $engage_j$) measure the extent of student engagement. In the second-stage regressions, we used the predicted values of *interesting*, *enjoy* and *engage* from the first-stage regressions as independent variables, along with control variables that captured student idiosyncrasies, to predict the overall usefulness of the animations in the learning process.

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Regression analysis

Animations and student learning experience

The results from the regressions in Equation (1) are reported in Table 2. Firstly, the estimated coefficient of $interesting_j$ is positive and significant in predicting the overall usefulness of animated videos ($p < 0.01$ and $p < 0.05$) in Models (1) and (2). This indicates how interesting an animated video was to students and directly relates to its usefulness as an instructional resource. Similarly, in Models (3) and (4), $enjoy_j$ is positively and significantly associated with $animation\_overall_j$ ($p < 0.05$ or better), which demonstrates that the more students enjoy watching the animations, the more likely they are to find the videos useful to their learning. Consistently, the coefficient of $engage_j$ is positive and significant ($p < 0.05$ and $p < 0.10$ in Models (5) and (6), respectively), which shows that improved student engagement is a significant predictor of the overall usefulness of the animated videos in the learning process.

Secondly, in Models (7) and (8), the coefficient of the variable $understand_j$ is positive and significant in predicting $animation\_overall_j$ ($p < 0.01$). These results show that helping students better understand the technical course content constitutes an important pedagogical benefit of the animations. Consistently, in Models (1) through (4) and (6), the variable $simplify_j$ is positive and significant in predicting $animation\_overall_j$ ($p < 0.05$ and $p < 0.10$). Furthermore, the coefficient of $visual_j$ is positive ($p < 0.01$) in Model (9), indicating that 'providing visual stimuli and graphic illustrations of abstract technical concepts' serves an important function that significantly determines the overall usefulness of animated instructional videos.

Thirdly, the coefficient of $flexible_j$ is positive and significant ($p < 0.01$) in Models (1), (3), (5), (7) and (9). Similarly, the coefficient of $selfpace_j$ is significant in Models (2), (4) and (6) ($p < 0.10$). These results show that providing flexibility and enabling self-paced learning also significantly contribute to the usefulness of animated videos.

Finally, the variable $refreshing_j$ is consistently positive and significant in Models (1) through (8) in predicting $animation\_overall_j$ ($p < 0.01$). This suggests that providing a refreshing change from conventional teaching materials is a significant aspect of the animations that explains their overall usefulness. Amongst the control variables, $lecture\_attend_j$ is significant in Models (1) through (9) ($p < 0.10$ or better), suggesting that students who regularly attend lectures, on average, tend to derive greater benefits from animated teaching videos.

Furthermore, we repeated the analyses by re-estimating the regressions in Equation (2) to predict $stimulate_j$, which captures the extent to which the animated videos stimulated student interest in the course. As reported in Table 3, the estimated coefficients and statistical significance of the key variables remained substantively similar to those reported in Table 2. Specifically, all four aspects of the animations, including $interesting_j$ (with $enjoy_j$ or $engage_j$ as alternatives), $understand_j$ (with $simplify_j$ or $visual_j$ as alternatives), $flexible_j$ (or $selfpace_j$) and $refreshing_j$ remained significant and positive ($p < 0.10$ or better) in predicting the extent to which the animated videos stimulated student interest in learning the course materials.

Aspects of animation design and student engagement

In this section, we estimate a two-stage model as specified in Equations (3) and (4) to further explore which aspects of the animation design contribute most significantly to improving student engagement. Models (1) through (3) of Table 4 report the results

Table 2. Animations and student learning experience.

Models	Interesting		Enjoy		Engage		Understand		Visual
	cartoon_ overall	cartoon_ overall	cartoon_ overall	cartoon_ overall	cartoon_ overall	cartoon_ overall	cartoon_ overall	cartoon_ overall	cartoon_ overall
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
interesting	0.206***	0.211**							
	(0.006)	(0.014)							
enjoy			0.146**	0.164***					
			(0.021)	(0.009)					
engage					0.155**	0.158*			
					(0.029)	(0.056)			
understand							0.346***	0.396***	
							(0.000)	(0.000)	
simplify	0.112*	0.151**	0.123*	0.155**	0.105	0.145*			
	(0.093)	(0.031)	(0.063)	(0.027)	(0.162)	(0.076)			
visual									0.399***
									(0.000)
flexible	0.215***		0.209***		0.226***		0.158***		0.290***
	(0.001)		(0.001)		(0.000)		(0.007)		(0.000)
selfpace		0.146*		0.146*		0.157*		0.075	
		(0.087)		(0.088)		(0.063)		(0.235)	
refreshing	0.335***	0.345***	0.373***	0.375***	0.360***	0.369***	0.333***	0.348***	
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	
cartoon_view	−0.007	−0.009	−0.009	−0.012	0.002	−0.001	0.001	−0.000	0.044

Table 2. (*Continued*)

Models	Interesting		Enjoy		Engage		Understand		Visual
	cartoon_overall	cartoon_overall	cartoon_overall	cartoon_overall	cartoon_overall	cartoon_overall	cartoon_overall	cartoon_overall	cartoon_overall
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	(0.758)	(0.711)	(0.722)	(0.630)	(0.944)	(0.969)	(0.981)	(0.998)	(0.129)
lecture_attend	0.053*	0.055*	0.059*	0.060**	0.061**	0.063**	0.058**	0.059**	0.066**
	(0.066)	(0.057)	(0.052)	(0.043)	(0.036)	(0.031)	(0.025)	(0.022)	(0.046)
cartoon_child	−0.044	−0.049	−0.061	−0.067	−0.057	−0.063	−0.029	−0.025	−0.048
	(0.276)	(0.295)	(0.191)	(0.211)	(0.190)	(0.215)	(0.380)	(0.460)	(0.313)
cartoon_enjoy	0.043	0.035	0.053	0.045	0.048	0.040	0.023	0.014	0.069
	(0.371)	(0.483)	(0.283)	(0.376)	(0.317)	(0.423)	(0.590)	(0.747)	(0.220)
age	0.023	0.039	0.015	0.029	0.021	0.038	0.047	0.063	0.042
	(0.579)	(0.369)	(0.730)	(0.529)	(0.625)	(0.409)	(0.255)	(0.146)	(0.353)
gender	−0.068	−0.062	−0.059	−0.055	−0.063	−0.062	−0.043	−0.045	−0.036
	(0.276)	(0.338)	(0.383)	(0.447)	(0.352)	(0.398)	(0.506)	(0.508)	(0.652)
constant	0.422	0.488*	0.503*	0.580*	0.475*	0.556*	0.440*	0.486*	0.770**
	(0.107)	(0.087)	(0.097)	(0.073)	(0.083)	(0.067)	(0.077)	(0.068)	(0.028)
N	134	134	135	135	133	133	134	134	136
adj. R^2	0.771	0.746	0.760	0.738	0.757	0.730	0.794	0.778	0.657

Notes: All variables are defined in Appendix A.
$*p < 0.1$, $**p < 0.05$, $***p < 0.01$.

Table 3. Animations and student interest in the course materials.

Models	Interesting		Enjoy		Engage		Understand		Visual
	stimulate	stimulate	stimulate	stimulate	stimulate	stimulate	stimulate	stimulate	stimulate
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
interesting	0.352***	0.338***							
	(0.000)	(0.001)							
enjoy			0.373***	0.378***					
			(0.000)	(0.000)					
engage					0.362***	0.346***			
					(0.001)	(0.005)			
understand							0.394***	0.424***	
							(0.000)	(0.000)	
simplify	0.183**	0.226**	0.168**	0.201**	0.133	0.183*			
	(0.023)	(0.024)	(0.043)	(0.043)	(0.154)	(0.097)			
visual									0.545***
									(0.000)
flexible	0.382***		0.350***		0.395***		0.359***		0.392***
	(0.000)		(0.000)		(0.000)		(0.000)		(0.000)
selfpace		0.392***		0.367***		0.397***		0.350***	
		(0.000)		(0.000)		(0.000)		(0.001)	
refreshing	0.173*	0.129	0.184**	0.129	0.167*	0.125	0.266***	0.233***	
	(0.054)	(0.116)	(0.039)	(0.107)	(0.072)	(0.156)	(0.001)	(0.007)	
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	135	135	136	136	134	134	135	135	137
adj. R^2	0.745	0.733	0.757	0.751	0.738	0.723	0.725	0.711	0.716

Notes: All variables are defined in Appendix A.
*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.

Table 4. Two-stage analysis: aspects of animation design and student engagement.

Models	Stage 1: student engagement				Stage 2: learning outcomes		
	interesting	enjoy	engage		cartoon_ overall	cartoon_ overall	cartoon_ overall
	(1)	(2)	(3)		(4)	(5)	(6)
voice_acting	0.392**	0.134	0.372**	interesting_p	0.646***		
	(0.011)	(0.382)	(0.018)		(0.001)		
character_design	0.482***	0.342**	0.565***	enjoy_p		0.761***	
	(0.002)	(0.036)	(0.000)			(0.000)	
dialogues	0.020	0.327**	0.244	engage_p			0.607***
	(0.899)	(0.043)	(0.114)				(0.000)
visual_cues	0.260*	0.225	0.236	cartoon_child	−0.023	−0.030	−0.023
	(0.070)	(0.155)	(0.114)		(0.786)	(0.704)	(0.776)
background_set	0.146	0.093	0.149	cartoon_enjoy	0.218**	0.232***	0.217**
	(0.437)	(0.659)	(0.417)		(0.013)	(0.007)	(0.013)
music_scoring	0.080	0.147	−0.121	age	0.051	0.070	0.056
	(0.724)	(0.506)	(0.485)		(0.471)	(0.345)	(0.432)
constant	3.429***	3.619***	3.328***	gender	0.026	0.021	0.013
	(0.000)	(0.000)	(0.000)		(0.848)	(0.872)	(0.919)
				constant	0.591	−0.029	0.755
					(0.503)	(0.975)	(0.353)
N	143	144	141	*N*	136	136	136
adj. R^2	0.100	0.068	0.137	adj. R^2	0.107	0.125	0.118

Notes: All variables are defined in Appendix A.
*p < 0.1, **p < 0.05, ***p < 0.01.

from the first-stage regressions. In Model (1), $character\_design_j$ is the most significant independent variable in predicting how interesting students found the animated videos ($interesting_j$) ($p < 0.01$), followed by $voice\_acting_j$ ($p < 0.05$) and $visual\_cues_j$ ($p < 0.10$). These results provide important insights by demonstrating that character design, voice acting, and visual cues and graphics are the most important features of the animations that make them interesting to students. Consistently, in predicting the enjoyability of animations ($enjoy_j$) in Model (2), $character\_design_j$ and $dialogues_j$ are both significant ($p < 0.05$), indicating that characters and dialogues contribute the most to enhance students' enjoyment of watching the animations. Similarly, in Model (3), $character\_design_j$ ($p < 0.01$) and $voice\_acting_j$ ($p < 0.05$) remained consistent in predicting student engagement ($engage_j$). Prior studies have explored the use of animated characters in educational videos (Cantley, Prendergast, and Schlindwein 2017; Johnson *et al.* 2013; Lee, Hsiao, and Ho 2014; Rosenberg-Kima *et al.* 2010). Consistent with prior evidence that the presence of an animated character increases students' interest in the subject matter (Johnson *et al.* 2013), we show that character design is of paramount importance in determining the enjoyability and engagement associated with animated teaching videos.

From these regressions in Equation (1), we calculated predicted values of the first-stage dependent variables, $interesting_j$, $enjoy_j$ and $engage_j$, which were then included in the second-stage regressions as explanatory variables. The results from the second-stage regression are reported in Models (4) through (6), Table 4. The coefficients of the predicted variables, $interesting\_p_j$, $enjoy\_p_j$ and $engage\_p_j$, are significant and positive in predicting students' overall rating of their learning experience using the animated videos ($p < 0.01$). These results further confirmed our expectation that engaging students and increasing students' interest in and enjoyability in learning constitute a crucial mechanism of improving their overall learning experience through animated videos. Finally, amongst the control variables, $cartoon\_enjoy_j$ is positive and significant ($p < 0.05$ or better) in Models (4) through (6), which shows that the more students enjoy (non-educational) cartoon programmes in general, the more they are likely to derive benefits from the animated instructional videos.

Student demographic characteristics and impacts on learning experience

Students' individual idiosyncrasies, including demographic characteristics, were expected to play an important role in determining their learning experience (Rosenberg-Kima *et al.* 2010). In this section, we conduct additional subsample analyses to provide further insights into the way in which student demographic characteristics moderate the relationship between animated teaching videos and learning experience.

Firstly, we re-estimate the regression models in Equation (1) by using two separate subsamples of female versus male students. The results are reported in Panel A, Table 5. In Models (1) through (4), we estimated the regressions over the subsample of only female students. The variables $interesting_j$ and $understand_j$ are significant in predicting the overall usefulness of animated videos ($p < 0.01$ and $p < 0.05$). We then re-estimate the regressions using the subsample of male students, as reported in Models (5) through (8). In contrast, neither $interesting_j$ nor $understand_j$ is consistently significant; instead the coefficient of $simplify_j$ is positive and significant ($p < 0.05$) in predicting $animated\_overall_j$. These results provide important novel insights into how

Table 5. Student demographic characteristics and impacts on learning experience.
Panel A. Student gender and benefits of animated videos

Models	Female students				Male students			
	cartoon_ overall	cartoon_ overall	cartoon_ overall	cartoon_ overall	cartoon_ overall	cartoon_ overall	cartoon_ overall	cartoon_ overall
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
interesting	0.229^{***}	0.214^{**}			0.228	0.246		
	(0.005)	(0.023)			(0.118)	(0.144)		
understand			0.359^{***}	0.388^{***}			0.268	0.318^{*}
			(0.000)	(0.000)			(0.126)	(0.064)
simplify	0.111	0.154^{**}			0.217^{**}	0.230^{**}		
	(0.133)	(0.030)			(0.046)	(0.041)		
flexible	0.181^{**}		0.124^{*}		0.216^{**}		0.199^{*}	
	(0.011)		(0.054)		(0.045)		(0.088)	
selfpace		0.155		0.082		0.152		0.102
		(0.153)		(0.277)		(0.277)		(0.426)
refreshing	0.361^{***}	0.380^{***}	0.349^{***}	0.370^{***}	0.200	0.185	0.370^{***}	0.368^{**}
	(0.000)	(0.000)	(0.000)	(0.000)	(0.143)	(0.373)	(0.008)	(0.030)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	82	82	83	83	52	52	51	51
adj. R^2	0.774	0.761	0.818	0.809	0.790	0.769	0.768	0.748

Table 5. *(Continued)*

Panel B. Student age and benefits of animated videos

Models	Older students (≥22)				Younger students (<22)			
	cartoon_ overall	cartoon_ overall	cartoon_ overall	cartoon_ overall	cartoon_ overall	cartoon_ overall	cartoon_ overall	cartoon_ overall
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
interesting	0.187*	0.132			0.251**	0.306***		
	(0.076)	(0.284)			(0.016)	(0.002)		
understand			0.261***	0.247**			0.462***	0.527***
			(0.003)	(0.011)			(0.000)	(0.000)
simplify	0.108	0.141			0.127	0.171*		
	(0.207)	(0.100)			(0.218)	(0.091)		
flexible	0.217***		0.173**		0.177		0.137	
	(0.005)		(0.031)		(0.142)		(0.100)	
selfpace		0.265***		0.198*		0.011		0.001
		(0.007)		(0.056)		(0.931)		(0.990)
refreshing	0.367***	0.359***	0.415***	0.407***	0.296***	0.366***	0.242***	0.306***
	(0.001)	(0.001)	(0.000)	(0.000)	(0.004)	(0.004)	(0.006)	(0.001)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	80	80	79	79	54	54	55	55
adj. R^2	0.715	0.711	0.718	0.711	0.827	0.811	0.872	0.862

Notes: All variables are defined in Appendix A.
*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.

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male and female students can derive different benefits from the animated teaching videos. While female students valued the fact that animated videos made learning more interesting and helped improve students' self-assessed understanding of the technical content, male students placed more emphasis on the benefit of animations in simplifying complex technical principles to assist them in their learning process.

Secondly, we also conducted similar subsample analyses using student age. We divided the observations into two groups by the sample median age (22 years old): one group consisted of older students (22 years of age or older), and the other consisted of younger students (21 years of age or younger). We re-estimated the regressions in Equation (1) using each subsample, and we report the results in Panel B, Table 5. As reported in Models (1) through (4), within the subsample of older students, $understand_j$ is significant in predicting $animated\_overall_j$ ($p < 0.01$ and $p < 0.05$ in Models (3) and (4), respectively), in addition to $flexible_j$ ($p < 0.05$ or better) and $selfpace_j$ ($p < 0.10$ or better). These results demonstrate that, for older students, the key benefits of animated videos lie in helping them attain better understanding of the technical content and facilitating flexible and self-paced learning. In contrast, when the regressions were re-estimated using the subsample of younger students, as reported in Models (5) through (8), *flexible* and $selfpace_j$ are no longer significant. While $understand_j$ is consistently significant ($p < 0.01$), $interesting_j$ is also a significant predictor of $animation\_overall_j$ ($p < 0.05$ and $p < 0.01$ in Models (5) and (6), respectively).

These results show that younger and older students derive benefits from animated videos for vastly different reasons. To younger students, making learning more interesting is an important aspect of interacting with animated videos. In contrast, older students, who are more likely to be self-motivated and career-conscious, do not place as much importance on being engaged; rather, they value having access to resources that facilitate flexible and self-paced learning. Another reason that can explain the importance of flexibility to older students is that they are more likely to have work commitments alongside their studies; consequently, this cohort of students prefers teaching resources that can enable them to engage in self-directed learning.

Conclusion

Key findings and implications

This study explores the use of animated videos in higher education, specifically to teach complex technical content in an advanced-level undergraduate accounting course. This is the first study that utilized a series of animations to serve the dual pedagogical objectives of explaining complex concepts and principles to improve students' understanding, while engaging students' interest and attention with dialogues, humour and real-world examples. Overall, the findings in this study provide numerous novel and valuable insights in relation to the use of animations in higher education.

Firstly, free-response survey comments and regression results both showed that animated teaching videos can enhance students' learning experience through four specific avenues, including (1) increasing student interest and engagement in the learning process, (2) improving students' self-assessed understanding of the materials by simplifying the technical concepts and providing visual aids, (3) facilitating flexible and self-paced learning and (4) providing a refreshing change from conventional teaching materials. We note that students' self-assessed level of understanding is commonly used as an empirical proxy for the level of understanding (e.g. Daigle, Hayes, and Morris 2014; Mather 2015; Richardson and Louwers 2010). These findings shed light on the multifaceted pedagogical benefits of using animated instructional videos in teaching complex materials.

Secondly, we explored the specific aspects of animation design that contribute to enhancing student engagement. Statistical evidence showed that character design, dialogues and voice acting in the animations constitute the most vital elements that explain students' interest, enjoyability and engagement during the learning process. These results provide valuable insights to inform future educators in relation to the design and production of animated resources.

Thirdly, this study provided important insights into the role of student idiosyncrasies in influencing their learning experience. The results showed that animated videos assist different student cohorts in significantly different ways. While all cohorts of students (regardless of gender and age) found animations useful for assisting their understanding of the technical content, female and younger students in particular valued the fact that animations make learning more interesting. To male students, a significant source of value added by animations lay in simplifying complex technical concepts. Finally, older students appreciated the flexibility provided by the animated teaching videos to enable self-directed learning. These findings contribute new insights into the pedagogical value of animations by informing future educators that, in designing effective animated teaching resources, one size does not fit all.

Limitations and directions for future research

There are several limitations to this study. Firstly, this study was conducted in the setting of an undergraduate course at an Australian university. This limits the generalizability of the findings, as they may not necessarily be extrapolated to other country settings, student cohorts, cultural backgrounds or year levels. Secondly, this study explored a variety of pedagogical benefits associated with the use of animated teaching videos. While some of these benefits as perceived by students (such as providing a refreshing change to conventional teaching resources) are unique to *animated* videos, other benefits (such as providing flexibility in learning) potentially apply to all recorded multimedia resources (whether animated or not). Thirdly, the empirical evidence in this study is based on self-reported responses from survey participants, rather than metrics derived from objective assessments. Further studies would be required to provide statistical evidence on the impacts of animated videos on the *actual* level of understanding, by adopting experimental or treatment-/control-group-based research methodologies. Finally, new technologies and pedagogical innovations are not costless. The design, development and production of animated videos require considerable resources. This study did not provide a direct cost–benefit analysis, as it lacks financial data on the direct and overhead costs associated with producing the animations, nor did it quantify the pedagogical benefits associated with animated videos in dollar value, as such quantification would be difficult if not impossible. Notwithstanding these limitations, this study documents evidence of improved student learning experience associated with an underexplored area of pedagogical innovation and offers novel insights and guidance to future educators to assist them in the process of producing animated resources.

Future studies may explore other aspects of students' demographic characteristics, such as cultural backgrounds or language capabilities (e.g. English as a first or additional language). In addition, while this study examined the use of animated instructional videos in the field of business education, adding to existing evidence from medical and science educators (e.g. Adam *et al.* 2017; Kelly and Jones 2007), animations also offer significant potential value to educators in other disciplines. Specifically, animated videos can be used not only as instructional tools to teach new concepts, but also to present case studies for students to apply and utilize their knowledge. Animated case studies can be particularly relevant to disciplines that require scenario-based learning, such as law, business and medicine (e.g. Adam *et al.* 2017). For example, legal educators can potentially derive significant pedagogical benefits by creating animations to bring to life vivid case scenarios for demonstration, problem discussion and assessment purposes. Furthermore, researchers can delve deeper into understanding the impacts of animations on students' learning experience from a psychological perspective, such as how they influence students' motivation and emotional commitment to learning, which may provide fruitful areas of future research.

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Appendices

Appendix A. Survey instrument.

No.	Questions	Semester(s)	Variable	Likert or other format
1	I find the animated (cartoon) videos interesting to watch.	both	interesting	1 2 3 4 5
2	I enjoy watching the animated (cartoon) videos.	2nd Sem	enjoy	1 2 3 4 5
3	The animated (cartoon) videos engage my attention and help me concentrate.	2nd Sem	engage	1 2 3 4 5
4	I find the animated (cartoon) videos helpful in assisting my understanding of the key concepts.	both	understand	1 2 3 4 5
5	The animated (cartoon) videos assist my learning by simplifying complex and technical concepts.	2nd Sem	simplify	1 2 3 4 5
6	The animated (cartoon) videos enhance my understanding by providing visual stimuli and graphic illustrations of abstract technical concepts.	2nd Sem	visual	1 2 3 4 5
7	The animated (cartoon) videos provide more flexibility to accommodate my busy schedule (including work commitments).	2nd Sem	flexible	1 2 3 4 5
8	The animated (cartoon) videos enable me to achieve better outcomes through self-paced learning (e.g. pause, rewind, repeat certain sections).	2nd Sem	selfpace	1 2 3 4 5
9	The animated (cartoon) videos present a refreshing change from regular teaching materials.	2nd Sem	refreshing	1 2 3 4 5
10	The animated (cartoon) videos stimulate my interest in the course materials.	both	stimulate	1 2 3 4 5
11	Overall, I find the animated (cartoon) videos helpful to my learning.	both	animation_ overall	1 2 3 4 5
12	I would like to see more animated (cartoon) videos in this course.	1st Sem	--	1 2 3 4 5
13	How much of the animated (cartoon) videos have you watched? (%)	2nd Sem	cartoon_watch	<49 50–64 65–74 75–84 >85%
14	How often do you attend lectures in person? (%)	both	lecture_attend	<49 50–64 65–74 75–84 >85%
15	What are the best aspects of the animated (cartoon) videos?	both	--	Free response

Appendix A. (*Continued*)

No.	Questions	Semester(s)	Variable	Likert or other format
16	What do you find to be the most memorable aspect(s) of the animated videos? (Please tick as many as relevant): voice acting, cartoon character design, dialogues, visual cues and graphics, background/set design, music and scoring.	2nd Sem	voice_acting; character_ design; dialogues; visual_cues; background_ design; music_scoring	Multiple selection
	Please tell us a little about yourself:			
17	Your gender	2nd Sem	gender	F M I'd rather not say
18	Your age	2nd Sem	age	<19 20–21 22–23 24–25 >25
19	How much cartoon/animated programs did you watch in your childhood?	2nd Sem	cartoon_child	1* 2* 3* 4* 5*
20	How much do you enjoy cartoon and animated programs in general?	2nd Sem	cartoon_enjoy	1^ 2^ 3^ 4^ 5^

Legend

Likert scale (Questions 1–12)	1 Strongly disagree	2 Disagree	3 Undecided	4 Agree	5 Strongly Agree
Likert scale* (Question 19)	1* Rarely	2* Occasionally	3* Sometimes	4* Often	5* Very frequently
Likert scale^ (Question 20)	1^ I dislike cartoons in general	2^ Not much	3^ Indifferent	4^ Reasonably well	5^ Very much