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Role of Interactivity in Learning from Engineering Animations

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Summary: This study examines the pedagogic value of incorporating sophisticated interactivity features into lessons on hand-held devices. Engineering students (Experiment 1) and non-engineering college students (Experiment 2) spent 5 min studying an animation showing a six-step maintenance procedure for a mechanical device called a Power Take-Off presented on an iPad. In both experiments, students who received high interactivity (i.e., rotation through dragging movements and zoom through pinching movements) reported higher interest but did not show better learning as compared to the low interactivity group (i.e., pause and continue buttons on the touch screen) or no interactivity group. Across two experiments, the interactivity hypothesis was supported in terms of increased interest but not supported in terms of improved learning. Thus, there was not support for the idea that increasing situational interest through high levels of interactivity primes deeper learning processes that produce better learning outcomes. Copyright © 2015 John Wiley & Sons, Ltd.

INTRODUCTION

Objective

The migration of educational materials to hand-held devices such as iPads affords the possibility of offering high levels of interactivity in presenting technical animations involving mechanical devices. For example, consider an animation showing a six-step maintenance procedure for a mechanical device called a Power Take Off as summarized in Figure 1. The touch screen interface of an iPad affords high levels of interactivity such as rotating the objects by dragging a finger or zooming by a pinching movement on the screen (as exemplified in Figure 2b) as well as low levels of interactivity such as pause and play buttons (as exemplified in Figure 2a). The purpose of this study is to assess the pedagogic value of incorporating interactivity features such as these into engineering lessons presented on hand-held devices.

Literature review

The introduction of computers as educational tools has led to calls for allowing learners to interact with instructional animations (Domagk, Schwartz, & Plass, 2010; Kriz & Hegarty, 2007; Mayer & Chandler, 2001; Sims, 1997). For example, Mayer and Chandler (2001) have found that information about how a system works presented in the form of animation is better understood when students are allowed to control the pace of presentation by means of pressing a ‘CONTINUE’ button. However, in a recent review, Scheiter (2014) concluded that convincing evidence is lacking for the instructional effectiveness of more sophisticated forms of learner control, and Lowe and Schnotz (2014) have noted the challenges of learning with animations. An explanation for this finding is that high level interactivity with animations can create extraneous cognitive load, which distracts from learning the content of the lesson, and furthermore many learners lack the metacognitive skill to make effective choices in using sophisticated interactivity options (Kalyuga, 2014; Sweller, Ayres, & Kalyuga, 2011).

STEM fields such as engineering have been identified as requiring spatial thinking (National Research Council, 2006; Utall & Cohen, 2012). In a recent review, Utall and Cohen show that some students might need aids to spatial thinking as they gain expertise in the spatial skills required in the discipline. Animation has been proposed as an aid to spatial thinking in STEM fields (Hoffler & Leutner, 2007; Mayer, Hegarty, Mayer, & Campbell, 2005; Tversky, Morrison, & Betrancourt, 2002), but research has not yielded a clear indication that animation is more effective than static illustrations except for manual procedural tasks such as tying a knot (Ayres & Paas, 2007). In addition, some researchers have suggested that learning can be improved through interactivity, such as by making animation more interactive through allowing for learners to zoom and rotate onscreen objects (Scheiter, 2014), although research has not yet yielded clear support for this suggestion. The rationale for adding these features is that learners become more interested and therefore try harder to make sense of material when they are physically engaged in manipulating instructional materials. The present study contributes to the investigation of interactive animation as a potential aid to spatial learning within the understudied context of interactive animation in engineering graphics.

Another important but underexplored aspect of cognitive theories concerns the role of motivation in multimedia learning, that is, the internal state that initiates, maintains, and energizes the learner’s effort to engage in learning processes (Mayer, 2014). Interest is a unique aspect of motivation characterized by increased attention, concentration, and affect (Hidi, 2006), and in later phases of development, interest is also a predisposition to reengage in activities over time (Hidi & Renninger, 2006). This study evaluates the role of situational interest, that is, interest that is environmentally triggered, and is assumed to elicit an affective reaction along with focused attention (Hidi, 2006).

According to interest theory, interactive learning environments respond dynamically to learners’ actions and are expected to promote deep cognitive processes, which results in active construction of new knowledge (Schiefele, 2009). Deep processing includes mentally reorganizing the presented

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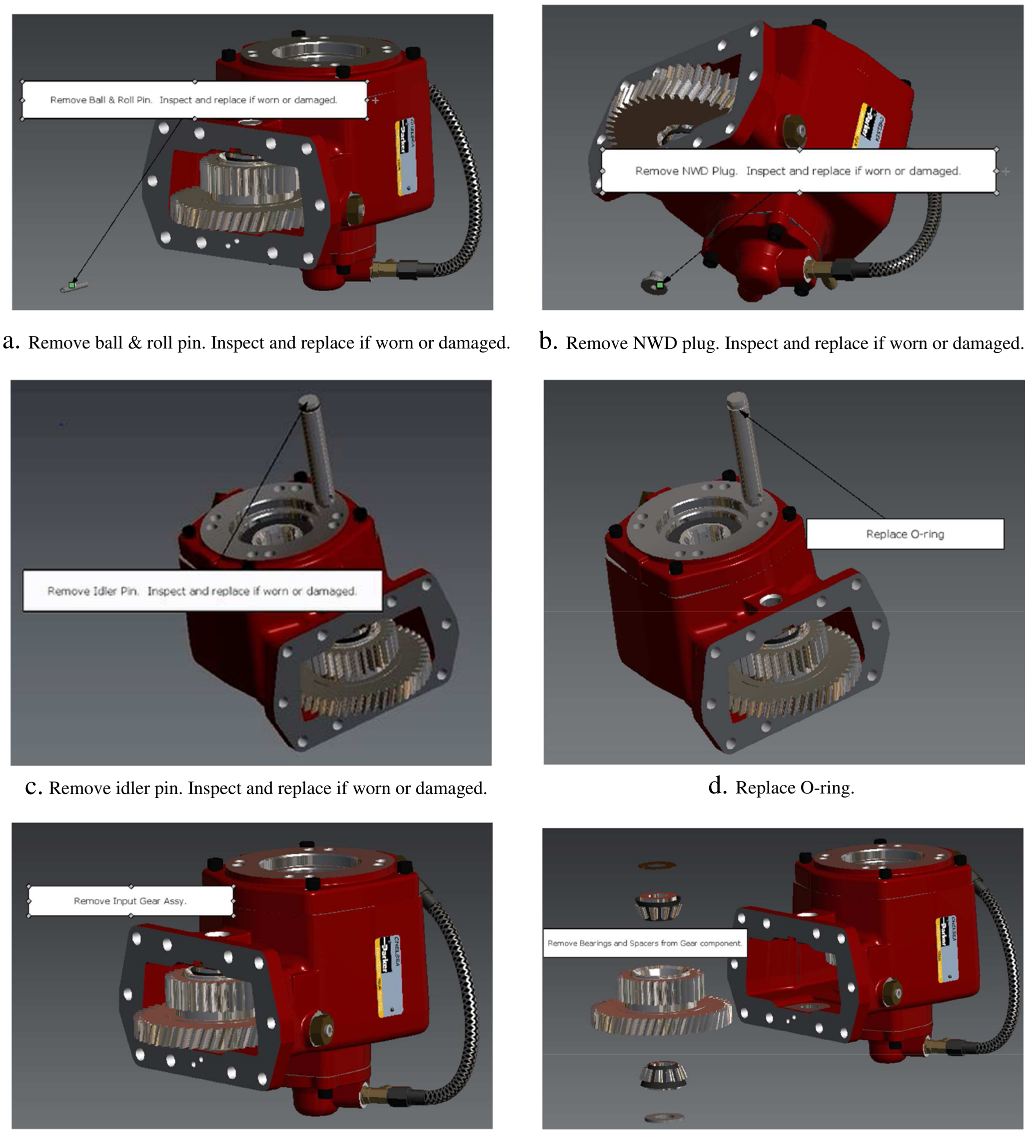

a. Remove ball & roll pin. Inspect and replace if worn or damaged. b. Remove NWD plug. Inspect and replace if worn or damaged.

c. Remove idler pin. Inspect and replace if worn or damaged. d. Replace O-ring.

e. Remove input gear assembly. f. Remove bearings and spacers from gear component.

Figure 1. (a) Remove ball and roll pin. Inspect and replace if worn or damaged. (b) Remove NWD plug. Inspect and replace if worn or damaged. (c) Remove idler pin. Inspect and replace if worn or damaged. (d) Replace O-ring. (e) Remove input gear assembly. (f) Remove bearings and spacers from gear component

material and integrating it with relevant prior knowledge, and is reflected in the ability to transfer what was learned to new situations (Mayer, 2011; National Research Council, 2013).

However, according to cognitive load theory (Sweller et al., 2011) the learner's physical activity within interactive settings may not necessarily translate into required cognitive processes and it may eventually impose extraneous processing demands on learner cognitive resources thereby hindering learning. According to this view, interactivity should be used sparingly (Lowe & Schnotz, 2014; Scheiter, 2014).

Predictions

The present study examines the interactivity hypothesis—the idea that high levels of interactivity cause an increase in the learner's interest, which in turn causes better learning of the material. The underlying theoretical account draws on interest theory which holds that students learn more deeply when they are interested in the content (Schiefele, 2009) and activity theory which holds that students learn more deeply when they actively manipulate the to-be-learned material (Scheiter, 2014). In the context of the present study the interactivity hypothesis predicts: (i) Students who study an engineering animation with high interactivity will rate the lesson higher on an interest scale than students who study the same lesson with low or no interactivity. (ii) Students who study an engineering animation with high interactivity will score higher on a learning outcome test than students who study the same lesson with low or no interactivity.

In contrast to these predictions, according to cognitive load theory (Sweller et al., 2011) sophisticated interactivity features may create extraneous cognitive load—cognitive processing that does not support the instructional objective—in which students waste their limited processing capacity on making decisions about what to do next. Thus, according to this view, students would not be expected to display better learning outcome scores when they study high interactivity engineering lessons rather than lessons with low interactivity, although they might like them better.

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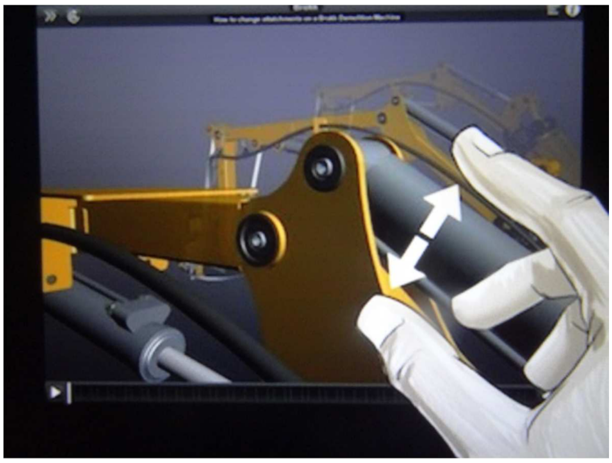
a.Example of instruction on how to play the animation.



b.Example of instruction on how to zoom in the animation.

Figure 2. (a) Example of instruction on how to play the animation. (b) Example of instruction on how to zoom in the animation

EXPERIMENT 1

The primary goal of Experiment 1 was to determine whether high-interactivity lessons on mechanical devices lead to better learning and higher interest ratings than low-interactivity lessons for engineering students.

Method

Participants and design

The participants were 80 college students in their 6th year of an Industrial Engineering program at Centro Universitário da FEI in São Bernardo do Campo, Brazil. The mean age was 23.91 years ($SD = 2.37$); there were 50 men and 30 women. The study was based on a between subjects design with low- *versus* high-interactivity level as the factor. Forty students were in the low-interactivity group (i.e., they studied an animation showing the maintenance procedure of the mechanical system presented on an iPad with pause, back, and forward buttons) and 40 students were in the high-interactivity group (i.e., they studied the same animation with additional touch screen features for zooming and rotating).

Materials and apparatus

The computer-based material consisted of two versions of a 1-min and 26-s-long 3D multimedia animation depicting six steps in the maintenance and repair of a mechanical device called a Power Take-Off:

(1) Remove ball and roll pin. Inspect and replace if worn or damaged.
(2) Remove NWD plug. Inspect and replace if worn or damaged.
(3) Remove idler pin. Inspect and replace if worn or damaged.
(4) Replace O-ring.
(5) Remove input gear assembly.
(6) Remove bearings and spacers from gear component.

Power Take-Offs (PTOs) are mechanical gearboxes that attach to apertures provided on truck transmissions and are used to transfer the power of the vehicle engine to auxiliary components, most commonly a hydraulic pump. The hydraulic flow generated by the pump is then directed to cylinders and/or hydraulic motors to perform work. In some PTO applications such as generators, air compressors, pneumatic blowers, vacuum pumps, and liquid transfer pumps, the PTO provides power, in the form of a rotating shaft, directly to the driven component. The animation included onscreen text describing each step depicted in the animation, as illustrated in Figures 1a to 1f.

The animation was created using Autodesk Inventor Publisher 2013 software and then published in two different file formats for use on iPads: MP4 in which students were able to press pause, play, forward, and back buttons on an iPad screen (i.e., low-interactivity lesson) and IPM (Inventor Publisher Mobile) developed by Autodesk Inc. in which students could also zoom in, zoom out, and rotate the mechanical device using an iPad touch screen (i.e., high-interactivity lesson). For the low-interactivity lesson, students were able to pause, play, move forward, and move back with the 3D animation by touching the appropriate buttons as illustrated in Figure 2a. For the high-interactivity lesson, in addition to having access to the low-interactivity features, students were able to touch and drag a finger around the screen to rotate the 3D animation or to pinch open and close to zoom in or zoom out the animation as illustrated in Figure 2b.

The paper-based materials consisted of a Situational Interest Questionnaire and a Learning Outcome Test[1]. The Situational Interest Questionnaire consisted of six statements adapted from the Situated Interest Survey (Linnenbrink-Garcia et al., 2010), such as ‘The animation used in this task is interesting’, ‘The type of interaction with the animation holds my attention’, and ‘I like the features available to control the animation’. This questionnaire was presented on a single-sided sheet of paper that requested participants to place a check mark on a seven-point Likert scale ranging from ‘totally disagree’ (1) to ‘totally agree’ (7) for each

[1] Experiments 1 and 2 also included a 10-item self-regulation survey adapted from Motivated Strategies for Learning Questionnaire (Pintrich, Smith, Garcia, & McKeachie, 1991), but this measure did not yield useful information and is not reported in this paper.

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one of the six statements. The Situational Interest Questionnaire also asked participants to report their age and gender.

The Learning Outcome Test consisted of eight questions, each presented on a single-sided sheet of paper: (i) 'How does a Power Take-Off provide power?' (answer: through a rotating shaft), (ii) 'What was the first action presented for the maintenance procedure?' (answer: remove ball and roll pin), (iii) 'What action follows the inspection and replacement of the idler pin?' (answer: replace O-ring), (iv) 'How many bearings are displayed at the end of the instruction?' (answer: two), (v) 'Give an example of an application for a Power Take-Off needed when the vehicle is stationary' (possible answers: car transporters or tippers), (vi) 'Give an example of application for a Power Take-Off when the vehicle is stationary or in movement' (possible answers: garbage trucks or cement mixer), (vii) 'Give an example of a factor that needs to be considered when specifying a Power Take-Off' (possible answers: the speed requirement of the driven component or the torque and horsepower requirement of the driven component), and (viii) 'Give an example of a factor that may affect the rotation speed of a Power Take-Off' (possible answers: the engine's revs or the gearbox ratio).

The apparatus consisted of 40 mobile iPad 3 tablet computers with 9.7-inch LED-backlit widescreen and 16 GB of memory.

Procedure

The experiment was conducted in two different classes consisting of 40 participants each. The paper materials (i.e., questionnaire and test sheets) and iPads were tagged with corresponding identification codes so the results for each participant could be properly matched while maintaining anonymity.

First, the experimenter briefly introduced the experiment and explained that performance in the study would not be counted in determining course grades. The experimenter randomly distributed the 20 iPads containing the MP4 files (low-interactivity lessons) and 20 iPads containing the IPM files (high-interactivity lessons) among the students, with each computer paired with a sealed envelope containing the Situational Interest Questionnaire and the Learning Outcome Test.

Second, the experimenter provided instructions on how to interact with a multimedia content using a sample animation file and a step-by-step 18-slide PowerPoint presentation. Participants were given 2 min to work with the sample files to ensure that they understood how to use the interactivity interface.

Third, participants were asked to open their corresponding multimedia files using the appropriate application (i.e., Video for the low-interactivity group and Inventor Publisher Mobile Viewer for the high-interactivity group) in order to study the instructional content during 5 min. At the end of the 5 min, the experimenter asked the participants to turn off the iPads and to open the sealed envelopes containing the Situational Interest Questionnaire and the Learning Outcome Test. Participants were given 10 min to complete the questionnaire and test. After 10 min, iPads, questionnaires, and tests were collected, and the experimenter thanked the students for their participation.

Results

Scoring

The interest score was computed by adding the six answers in the Situational Interest Questionnaire, each ranging from 1 ('totally disagree') to 7 ('totally agree'), and dividing by 6, yielding a maximum score of 7 points. The learning outcome score was determined by adding the number of correct answers (1 point each for correct and 0 points for incorrect) for the eight questions on the Learning Outcome Test, yielding a maximum score of 8 points. The test was scored by two raters, with differences (which occurred on less than 5% of the items) resolved by revising the scoring rubric for clarity.

Do the low- and high-interactivity groups differ on basic demographic characteristics?

A first step is to determine whether the groups are equivalent on basic demographic characteristics. A *t*-test indicated that the groups did not differ significantly (at $p < .05$) on mean age. A chi-square analysis (at $p < .05$) indicated that the groups did not differ significantly in the proportion of males and females. We conclude that random assignment produced groups that are equivalent in basic characteristics.

Does increasing interactivity improve student interest?

The first column in Table 1 shows the mean interest rating (and standard deviation) for each group. A *t*-test showed that the mean interest rating of the high interactivity group was significantly greater than for the low interactivity group, $t(78) = 4.34$, $p < .001$, Cohen's $d = 0.97$ [95% CI: 0.50, 1.43].

Does increasing interactivity improve student learning outcomes?

The second column in Table 1 shows the mean learning outcome score (and standard deviation) for each group. A *t*-test found that the mean learning outcome score of the high-interactivity group was not significantly different than for the low interactivity group, $t(78) = 0.88$, $p > 0.05$, $d = 0.20$ [95% CI: −0.24, 0.64]. Thus, although engineering students liked the high-interactivity lesson better than the low-interactivity lesson they did not learn better from it. This is the main finding of Experiment 1.

EXPERIMENT 2

Experiment 1 showed that adding high interactivity to mechanical animations resulted in improved interest but not in improved learning for engineering students. The goal of Experiment 2 was to examine the effects of high interactivity in

Table 1. Mean interest rating and learning outcome score for low-interactivity and high-interactivity groups—experiment 1

Group	Interest score		Learning outcome score	
	M	*SD*	*M*	*SD*
Low interactivity	5.55	1.05	3.38	1.56
High interactivity	6.40*	0.64	3.68	1.49

Asterisk (*) indicates significant difference at $p < .05$. Maximum interest score is 7; maximum learning outcome score is 8.

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learning with mechanical animations for non-engineering students. In order to give a broader test of the interactivity hypothesis—i.e., the idea that greater interactivity leads to higher interest and better learning—Experiment 2 added a no-interactivity group in addition to the low-interactivity and high-interactivity groups used in Experiment 1, and expanded the Learning Outcome Test for a more comprehensive measure of learning.

Method

Participants and design

The participants were 68 college students (7 men and 61 women) recruited from the Psychology Subject Pool at the University of California, Santa Barbara. The mean age was 18.60 years (SD = 0.80), and none of the students was majoring in engineering. The study was based on a between-subjects design with three levels of interactivity (high, low, and no). Twenty-four students served in the high-interactivity group, 20 students served the low-interactivity group, and 24 students served the no-interactivity group.

Materials and apparatus

The computer-based material consisted of the low-interactivity and high-interactivity versions of the animation lesson used in Experiment 1 as well as a version that offered no interactivity in which the student could only view the continuous animation without interruption (and repeat it).

The paper-based materials consisted of an Informed Consent Form, Participant Questionnaire, Situational Interest Questionnaire, Post-Questionnaire, and Learning Outcome Test.

The Participant Questionnaire asked for demographic information including age, gender, and experience with mechanical devices. The Situational Interest Questionnaire was the same than the one used in Experiment 1. The Post-Questionnaire consisted of two questions. The first question was 'How difficult was the lesson you just received?' and the possible answers were 'Difficult', 'Somewhat difficult', 'Average', 'Somewhat easy' and 'Easy'. The second question was 'How much effort did you use for the lesson you just received?' and the possible answers were 'High effort', 'Somewhat high effort', 'Moderate amount of effort', 'Somewhat low effort' and 'Low effort'.

The Learning Outcome Test included (i) the same eight test questions as in Experiment 1, (ii) a recall question on a single-sided sheet of paper asking participants, 'Please write down all the information you can remember from the lesson', (iii) two matching questions consisting of a single-sided sheet of paper containing two images of the Power Take-Off with an arrow pointing to a part on each and instructions for the student to 'Please write the name of each part in the appropriate box', and (iv) an ordering item, also on a single-sided sheet of paper, which presented six screen shots with printed descriptions of each of the six steps of the maintenance procedure, along with instructions: 'Please write 1 in the box next to the first step, 2 in the box next to the second step, and so on, to indicate the order the steps were presented during the lesson'.

The apparatus consisted of four mobile iPad tablet computers with 9.7-inch LED-backlit widescreen and 16 GB of memory.

Procedure

Students were randomly assigned to treatment and tested in groups of 1 to 4 per session. The experiment took place in a lab where each participant was seated in an individual cubicle that included a desk with an iPad loaded with the animation corresponding to the student's treatment group (i.e., no, low, or high interactivity).

Each session started with the experimenter briefly explaining the experiment to the participants and highlighting that performance in the study would not be counted in determining course grades. The participants were asked to read and sign the Informed Consent Form if they agreed to participate of the experiment. After signing the Informed Consent Form participants filled out the Participant Questionnaire and, then, the experimenter provided instructions on how to interact with the animation using sample files and a step-by-step PowerPoint presentation, as in Experiment 1. Participants had 2 min to work with the sample files to ensure that they understood how to interact with the animation, and after that, participants were instructed to load the lesson file and play with it for 5 min using the interactivity functions available in their assigned treatment group.

After 5 min with the lesson, participants were told to close the iPad cover and the experimenter distributed the recall sheet, which participants had 2 min to answer. Then, the experimenter started distributing the eight test questions (as used in Experiment 1), one at a time, giving participants 1 min to answer each question. Next, participants worked on the matching sheet, which was collected after 1 min. Then, the experimenter distributed the ordering sheet, which participants had 2 min to complete.

In the last part of the experiment, participants filled out the Situational Interest Questionnaire and the Learning Style Questionnaire at their own rates. Finally, the experimenter collected the materials and thanked the students for their participation.

RESULTS

Scoring

Scoring of the first eight questions on the Learning Outcome Test was the same as in Experiment 1. The interest score was also determined the same way as in Experiment 1. A score was determined for each of the two answers in the Post-Questionnaire with 'Difficult' = 5 points, 'Somewhat difficult' = 4 points, 'Average' = 3 points, 'Somewhat easy' = 2 points, and 'Easy' = 1 point for the first question; and 'High effort' = 5 points, 'Somewhat high effort' = 4 points, 'Moderate amount of effort' = 3 points, 'Somewhat low effort' = 2 points, and 'Low effort' = 1 point for the second question yielding a score from 1 to 5 points for each. The recall question was scored by determining the number of the 14 main idea units, as shown in Appendix A, that the participant included in their written response regardless of specific wording, yielding possible scores of 0 to 14. The recall test was

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scored by two raters, with differences (which occurred on less than 5% of the items) resolved by revising the scoring rubric for clarity. The matching items were scored by determining how many parts were correctly named, yielding possible scores of 0 to 2. The ordering items were scored by determining the number of correctly ordered steps, yielding possible scores of 0 to 6. An overall Learning Outcome score was determined by adding up the comprehension, recall, matching, and ordering scores, yielding possible scores of 0 to 30. The Learning Outcome score is greater than in Experiment 1 because it involves more test items.

Do the groups differ on basic demographic characteristics?
As in Experiment 1, a preliminary step is to determine whether the groups are equivalent on basic demographic characteristics. An analysis of variance (ANOVA) indicated that the groups did not differ significantly (at $p < .05$) on mean age. A chi-square analysis (at $p < .05$) indicated that the groups did not differ significantly in the proportion of males and females. We conclude that random assignment produced groups that are equivalent in basic characteristics.

Does interactivity affect interest?
As in Experiment 1, the first goal of this study was to determine whether the interactivity level might affect the interest of the participants, as predicted by the interactivity hypothesis. The left columns of Table 2 show the mean interest scores and standard deviations for the three interactivity groups. An ANOVA based on these data showed that the groups differed significantly in their reported interest, $F(2, 65) = 3.877$, $p = .026$, with Tukey tests (at $p < .05$) indicating that the high interactivity group reported significantly higher interest than the other groups. This pattern of results is consistent with the results of Experiment 1 and supports the prediction that high interactivity produces greater interest than low interactivity or no interactivity.

Does interactivity affect learning outcome?
The second goal of this study was to determine whether interactivity level might affect learning outcome, as measured by the Learning Outcome Test. The right columns of Table 2 show the mean learning outcome score and standard deviation for each group[2]. As in Experiment 1, an ANOVA showed no significant difference among the groups on learning outcome score, $F(2, 65) = 0.982$, $p = .380$, and thus no evidence to support the interactivity hypothesis that greater interactivity leads to better learning. Similar to Experiment 1, the overall results of Experiment 2 show that students like high interactivity better but do not learn better with it. Thus, a major contribution of Experiment 2 is that it replicates the pattern of results of Experiment 1 with expanded measures of learning outcome and with non-engineering students.

[2] In Experiment 2, the means (and standard deviations) for the no, low, and high interactivity groups, respectively, on each component of the Learning Outcome test are: 3.21 (1.35), 3.95 (1.75), and 2.54 (1.12) on part 1; 3.83 (2.71), 4.50 (2.56), and 4.25 (3.44) on part 2; 0.92 (0.50), 1.10 (0.55), and 0.92 (0.72) on part 3; and 4.42 (2.06), 5.05 (1.67), and 4.50 (2.26) on part 4.

Table 2. Mean interest rating and learning outcome score for no-interactivity, low-interactivity, and high-interactivity groups—experiment 2

Group	Interest score		Learning outcome score	
	M	*SD*	*M*	*SD*
No interactivity	4.38	1.51	12.21	6.99
Low interactivity	4.66	1.25	14.60	5.55
High interactivity	5.37*	1.02	12.38	5.87

Asterisk (*) indicates significant difference at $p < .05$. Maximum interest score is 7; maximum learning outcome score is 30.

Do the groups differ on self-reported effort and difficulty?
The mean rating (and standard deviation) for the no, low, and high interactivity groups, respectively, were 3.33 (0.76), 3.50 (0.89), and 3.29 (1.04) for effort; and 3.33 (1.34), 3.45 (1.00), and 3.58 (0.78) for difficulty. The three groups did not differ significantly on mean effort rating, $F < 1$, or mean difficulty rating, $F < 1$, suggesting lack of support for the idea that increasing the level of interactivity increases the depth of cognitive processing during learning.

DISCUSSION

Empirical contribution

In both Experiment 1 (with engineering students) and Experiment 2 (with non-engineering students) adding a high level of interactivity to a tablet-based lesson depicting how to perform a maintenance procedure on a mechanical device resulted in higher reported interest but not in better learning.

Theoretical contribution

The interactivity hypothesis states that students like learning with highly interactive multimedia lessons more than learning from multimedia lessons that have low or no interactivity (i.e., interactivity increases interest), which leads to better learning outcomes (i.e., interactivity improves learning outcome). Across two experiments, the interactivity hypothesis was supported in terms in increased interest (hypothesis 1) but not supported in terms of improved learning (hypothesis 2). Thus, there is not evidence that increasing situational interest through higher levels of interactivity leads to deeper cognitive processing reflected in better learning outcomes, consistent with past research on situational interest.

Practical contribution

When the goal of instruction is to increase student interest, then high levels of interactivity are warranted; but when the goal of instruction is to improve student learning (as is generally the case), high levels of interactivity are not generally warranted.

Methodological contribution

As multimedia instruction migrates from books, desktop computers, and classroom videos to interactive hand-held devices with touch screens, it is worthwhile to identify the pedagogical value of interactivity features afforded by these devices. The present study contributes to a growing literature on the use of

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tablets (such as iPads) as a means of providing students with more control of multimedia learning environments (Scheiter, 2014; Sung & Mayer, 2013), by exploring the effects of high interactivity features such as rotation and zoom compared to traditional forms of interactivity such as play and pause.

Limitations and future directions

This study is limited by focusing on a single, short lesson about one device with an immediate test, so future research is needed to examine the role of interactivity with different materials and delayed tests. This study is limited by focusing on self-report surveys to measure interest and motivation, so future research is needed that employs more direct measures. Another limitation is that we did not collect direct measures of learning activity (such as deep learning processes) or cognitive load during learning, so future work is needed to develop appropriate methods for doing so. Finally, it would be useful to directly compare the effects of interactivity with engineering students and non-engineering students within the same experiment.

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APPENDIX A

Idea units for the recall test

1. Remove ball and roll pin.
2. Inspect and
3. replace if worn or damaged.
4. Remove idler pin.
5. Inspect and
6. replace if worn or damaged.
7. Replace O-ring.
8. Remove bearings and spacers from gear component.
9. Power Take-Offs (PTOs) are mechanical gearboxes
10. that attach to apertures provided on truck transmissions
11. to transfer the power of the vehicle engine to auxiliary components
12. The hydraulic flow produced by the pump activates cylinders or hydraulic motors to perform work.
13. The PTO provides power, in the form of a rotating shaft,
14. directly to the driven component.

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