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Interest-driven video creation for learning mathematics

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Abstract The teacher-directed approach characteristic of the traditional classroom normally adopted by mathematics teachers provides few opportunities for students to develop their mathematical problem-solving skills and little encouragement for them to engage in conversation. Furthermore, this approach might not be flexible to students' individual learning needs and could generate low interest in mathematics among students. To reduce these learning problems, this study proposes a student-centered learning activity called *interest-driven video creation,* which adopts interest-driven creator (IDC) theory in its design. By viewing cognitive apprenticeship strategies as subcomponent concepts of the creation loop in IDC theory, this study could articulate and enrich the creation loop model of IDC design in mathematics. In an interest-driven video creation activity, students solved mathematics word problems through individual and group creation of tutorial videos. With these videos, students could teach their fellow classmates by discussing mathematics concepts and sharing ideas. The preliminary results reveal significant improvements in mathematics achievement and show that both high- and low-achieving students have positive attitudes and low anxiety regarding the activity and perceive both mathematics and the learning activity to be highly useful. In addition, the students' perceptions of the benefits of the activity for learning are positive overall. Students also agree that they enjoy and engage in the video creation activity and that the activity helps them to learn mathematics better and improves their communication skills, teamwork skills, and filmmaking techniques.

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Introduction

For students learning mathematics, the mastery of mathematical problem-solving is essential. Hence, mathematical problem-solving skills are regarded as a measure of mathematics knowledge for many students. Mathematical problem-solving skills are also defined as one of the most important mathematics skills. Moreover, developing effective problem solvers is a primary goal for K-12 mathematics instruction according to the *Principles and Standards for School Mathematics* [National Council of Teachers of Mathematics (NCTM) 2000].

In previous studies, the relationships among learning attitudes, interest, anxiety, and outcomes have been demonstrated. Harackiewicz et al. (2008) found that students' learning attitudes were positively related to learning interest. Interest is a significant predictor of student achievement in mathematics (Schiefele and Csikszentmihalyi 1995). Krapp (1999) also emphasized that a lack of interest leads to low performance. Schraw et al. (2001) reviewed the history of interest research and found that learning interest influenced students' learning performance. Moreover, Harackiewicz and Hulleman (2010) claimed that being interested in a topic leads to better outcomes. The findings of the 2015 Trends in International Mathematics and Science Study (TIMSS) survey indicated that achievement in mathematics was positively related to learning interest (Mullis et al. 2016). Jansen et al. (2016) also highlighted that students with greater interest showed higher achievement in mathematics. These findings indicate that there are a correlation between attitudes and interest and a correlation between interest and outcomes. In addition, Wu et al. (2012) found that mathematics anxiety has a negative impact on math achievement. Moreover, students' low interest and negative attitudes can lead to anxiety and then generate low performance (Aksu and Bikos 2002). However, the findings of Yu and Singh (2018) showed a nonsignificant relationship between interest and mathematics performance. The finding of Wong and Wong (2019) could account for the inconsistent results of related findings. They found that interest is not significantly related to mathematics performance for high-achieving students, but interest has a significant, positive relationship with mathematics performance for low-achieving students. High-achieving students might still study hard even when they have low interest. The TIMSS results also showed that a percentage of low-achieving students had negative attitudes and low interest in mathematics. Hence, finding ways to improve the students' learning attitudes and interests and the achievements of students with decreasing anxiety is an educational issue that is worthy of investigation, particularly to help low-achieving students.

Teachers' approaches to teaching have an impact on students' interest in and attitudes toward learning (Savelsbergh et al. 2016). However, in traditional mathematics classroom instruction, teachers commonly adopt a teacher-directed approach. For example, Menegale (2008) found that teachers dominate the discussion time in class and that all students receive the same information from the teacher when he/

she addresses the entire class at the same time. Battista (1999) observed that school mathematics involves an endless sequence of memorizing and forgetting facts and procedures that, from the students' perspective, make little sense to them. Students only learn by rote and use a few techniques that their teachers teach them to answer questions (Menegale 2008). Lerkkanen et al. (2012) also emphasized that teacher-directed instruction activities are not flexible; they engage students in rote activities, provide fewer opportunities for students to develop interpersonal skills, and do not engage students in conversation.

Recently, a growing number of researchers have focused on student-centered learning employing video and technology in efforts to reduce the learning problems mentioned above. For example, researchers have indicated how video instruction can be adapted to students' individual learning needs (Hoogerheide et al. 2014; Ouwehand et al. 2015; Pan et al. 2012). Moreover, researchers and teachers have combined video instruction and video creation to engage students in creating videos in K-12 and higher education (Schuck and Kearney 2006; Henderson et al. 2010; Palmgren-Neuvonen and Korkeamäki 2014). This approach requires students to communicate, reflect on their understandings, and make their understandings visible to others. It also provides new opportunities and challenges in mathematics education (Engin 2014; Hulsizer 2016).

Additionally, interest-driven creator (IDC) theory (Chan et al. 2015; Wong et al. 2015; Chan et al. 2018) suggests that the design of any learning activity should consider how students' interest in a creation activity can be nurtured. It has been increasingly emphasized that students learn according to what they are interested in and thereby actively participate in learning. Kong and Li (2016) also found that, if students are interested in academic topics, their learning is enhanced. When students are motivated to learn about their interests for creation, they develop their own learning abilities and habits and create new knowledge or artifacts through repetitive learning activities to become lifelong creators. IDC theory proposes a framework with three anchored concepts (*interest*, *creation*, and *habit*) of learning design, and it suggests that the use of the framework with the appropriate instructional method and technological support can develop students' interest in and learning of academic topics (Chan et al. 2018). Moreover, to reduce the complexity of activity design, IDC theory provides designers with these three anchored concepts to design a learning activity at the macro-level. When further experimentation and investigation are conducted, each anchored concept incorporates several subcomponent concepts at the micro-level to support students' learning (Chan et al. 2018).

To enrich and implement IDC theory design in mathematics, the purpose of the present study was to develop an interest-driven video creation learning activity by adopting a creation loop model of IDC theory. In addition, Kuo et al. (2012) emphasized that low-achieving students require sufficient one-to-one support from their teachers or peers to experience in-depth cognitive development, and they found that using the cognitive apprenticeship strategies (Collins et al. 1989) could promote both high- and low-achieving students' problem-solving skills. In this study, six cognitive apprenticeship strategies were used as subcomponent concepts of the creation loop model to guide students to improve their mathematical problem-solving skills and to collaborate with peers. To improve both high- and low-achieving students' learning attitudes, interest, and achievement with decreasing anxiety, video creation and computer technologies have been employed as learning tools to enhance students' learning attitudes and interest. The study is based on the assumption that, for both high- and low-achieving students, engagement as creators in video creation activities might promote not only their mathematical problem-solving skills but also their interest in learning. Thus, the study evaluates students' mathematics learning achievement, attitudes, anxiety, and thoughts in elementary mathematics classrooms.

Literature review

Videos for teaching and learning

The role of videos is essential to interest-driven video creation learning activities. Compared to the use of teacher-directed approaches, the use of videos as instructional tools for teaching and learning can have more cognitive and emotional impacts for students, such as fostering deeper learning (Mitra et al. 2010), improving attitudes toward learning (Shyu 2000; Kinnari-Korpela 2015), generating learning interest (Lonergan 1984; Kearney and Schuck 2005; Khan et al. 2010; Kamariah 2018), building connections with peers (McCombs and Liu 2007; Berk 2009; Tarantino et al. 2013), and fostering creativity (Berk 2009; Nordstrom and Korpelainen 2011). From a teaching viewpoint, instructors have been recording tutorial videos for nearly as long as the format has existed (Guo et al. 2014). Felton et al. (2001) suggested that the use of video instruction to support conventional lectures is a more effective teaching technique than conventional lectures. Moreover, many researchers have posited that videos offer a nurturing value for instruction and can serve as an effective way to motivate students, capture and maintain their attention, and provide learning satisfaction (Choi and Johnson 2005, 2007; Mackey and Ho 2008; Pan et al. 2012). From a learning perspective, Pan et al. (2012) argued that learning from tutorial videos can foster students' learning autonomy. For example, video instructions provide students with different techniques to explain the same content and offer students easy and repeated access to content, such as by skipping, pausing, rewatching, or rewinding to sections to review incomprehensible content until they have achieved understanding.

However, despite the aforementioned benefits, video instruction has a number of disadvantages. Pan et al. (2012) noted that a main problem with video instruction was that students tended to stop watching if the video was 40 min or longer. Learning from a long video might be difficult due to the limited capacity of students' working memory (Baddeley 1992; Goldstein 2010; Ormrod 2008). Guo et al. (2014) conducted an empirical study to investigate how video production affects student engagement and found that engagement dropped sharply after watching a video for six minutes. Miller and Redman (2010) showed tutorial videos between three and five minutes in length to undergraduate students and found that the tutorial video content improved students' satisfaction and perception of value. In summary, instructors must plan their lessons carefully and specifically in a short video format to maximize students' engagement. In this study, tutorial videos were designed as scaffolds (Vygotsky 1978; Wood et al. 1976; Pan et al. 2012) to give students a possible model to learn mathematics concepts and filmmaking techniques. Each video was typically less than four minutes in length to ensure that the students were engaged and learning.

Student-created videos and mathematics learning

A student-created video activity is an activity that involves the use of videos as instructional tools for teaching and learning; it refers to a process by which students independently or collaboratively engage in a learning activity related to the recording of digital video (Henderson et al. 2010). Research has suggested that student-created video activities are useful in helping students to construct their own knowledge (Jordan et al. 2015). This approach can motivate students to develop from novices to experts by comprehending, communicating, and creating (Engin 2014). In addition, Rodriguez et al. (2012) found that the creation of a video involves higher levels of cognitive processing to be able to explain a topic to peers. In their study, Yang and Wu (2012) asked high school students to create a video with digital stories and determined that the approach increased students' understanding of course content and developed their critical thinking skills. Additionally, Woodcock (2012) found that student-created video presentations could help reduce students' anxiety about oral presentations.

Some studies have examined student-created videos in different subjects in the higher education context, such as history (e.g., Levin 2003; Swain et al. 2003), physical education (e.g., Lim et al. 2009), marketing and accounting (e.g., Greene and Crespi 2012; Holtzblatt and Tschakert 2011), chemistry (e.g., Jordan et al. 2015), media studies (e.g., Crean 2001), language (e.g., Ludewig 2001), and mathematics (e.g., Hulsizer 2016). These researchers have reported positive results regarding students' increased motivation and performance. In the K-12 education context, for example, Banaszewski (2002) found that student-created videos employed to develop and share stories in the fourth and fifth grades supported the development of confidence in writing. Ross et al. (2003) discussed the ways in which student-created videos promoted elementary students' scientific skills. Cooper et al. (2007) also described the use of student-created videos to support K-12 students' multiliteracy development. Kearney and Schuck (2005) analyzed five case studies in five schools (two primary and three secondary schools) in Australia and reported some benefits to student learning outcomes, such as literacy skills; communication and presentation skills; organization and teamwork skills; higher-order thinking skills; and student confidence, responsibility, and autonomy. Morgan (2013) discussed and listed different types of activities and outcomes that teachers can implement for student-created video projects to enhance K-12 students' motivation, multimodal literacy, problem-solving skills, and content knowledge. The findings from Smith (2016) indicated that student-created videos could provide an authentic and meaningful opportunity for students to visualize their own metacognitive growth by both qualifying the value of the students' learning experience and quantifying the process for the educator tasked with documenting learning outcomes.

However, there has been little research providing learning activities that combined the individual and group creation learning processes in an IDC design to support students in reflecting, sharing, integrating ideas, and extending their ability to create videos and generate topic knowledge. In this study, a student-created video learning activity was developed and used to improve elementary students' mathematical problem-solving skills. Furthermore, the activity provided opportunities for students to engage in conversation to develop their communication and teamwork skills.

Interest-driven creator theory in relation to student-created videos

The process of students creating a tutorial video can be regarded as learning through creation. In recent years, an increasing number of studies have invested efforts in nurturing students as creators. IDC theory is a general design theory that was proposed by a group of researchers in Asia. It proposes a holistic developmental/design framework for technology-supported learning activities and environments in twenty-first-century education to guide and nurture young students as lifelong creators by develop their learning *interests*, capabilities for *creation*, and learning *habits*, which are the three anchored concepts of IDC theory (Chan et al. 2015, 2018; Wong et al. 2015). *Interest* is important for learning because students enjoy the learning process when learning is relevant to their interests (Chan et al. 2018). In addition, students' learning performance is positively related to their learning interests (Mullis et al. 2016). *Creation* is the core of a learning activity because students' creative processes represent their learning processes; creation renders learning outcomes visible, makes learning more enjoyable, and satisfies students' curiosity (Chan et al. 2018). *Habit* is a daily repetitive behavior that helps students to accumulate achievements, build confidence, and maintain an effective learning cycle to develop learning habits (Chen et al. 2016; Chan et al. 2018). In short, when students are driven by interest to engage in creation and repeat this learning process in daily learning activities or tasks, they eventually develop knowledge or artifact creation habits (Kong and Li 2016; Chan et al. 2018).

Some studies have employed IDC theory models of enhancing interest and learning. For example, Wong et al. (2016) reviewed the literature of the three-component interest loop model, which comprises *triggering*, *immersing*, and *extending*, to propose three design strategies for enhancing the effectiveness of learning activities. Chan et al. (2016) described the three components of the creation loop model, namely *imitating*, *combining* and *staging*, based on the literature and discussed how these components support the development of creation capability. Chen et al. (2016) outlined the three-component (*cuing environment*, *routine,* and *harmony*) habit loop proposed by IDC theory and described how these components nurture students' habits of creation. Kong and Li (2016) used IDC theory to propose the design of an interest-driven approach to guide students in learning to code in computer programming education and suggested that students could acquire logical thinking and mathematical problem-solving skills by learning to code.

Based on the above, to enhance the students' interest and learning in mathematics via video creation, this study proposed a student-created video learning activity, namely an interest-driven video creation learning activity. The activity enables students to develop their interest in learning by collaborating in video creation, and it structures individual and group learning processes based on the creation loop model proposed by IDC theory to allow students to become progressively immersed in the creation process. When students participate in this learning activity, their learning interest and learning are enhanced. The creation process also helps students to develop their own ways of learning, which eventually become their habits.

Cognitive apprenticeship in relation to the creation loop model

Student-created video activities, in which students play the role of the expert to construct their own mathematical problem-solving processes to teach, share and present to peers, can be regarded as a form of the cognitive apprenticeship method. Cognitive apprenticeship is an instructional design model that involves an expert guiding apprentices in learning in a domain (Collins et al. 1989). Through the expert's demonstration and explanation of authentic contexts, apprentices can acquire cognitive skills (e.g., mathematical problem-solving skills) through observation and active learning and then apply these skills to solve the same or similar problems (Collins et al. 1989, 1991). Cognitive apprenticeship not only retains the characteristic authentic learning and practical experience acquisition of traditional apprenticeship, but it also emphasizes learners' cognitive and exploration processes to help them learn.

Collins et al. (1989) proposed six cognitive apprenticeship strategies to support learning: (a) modeling, in which the teacher performs a task and explains his/her practical experience and methods for students to observe and understand; (b) coaching, in which the teacher observes, advises, and corrects while students practice the methods; (c) scaffolding (Wood et al. 1976), in which the teacher progressively helps students by increasing the complexity of problems and decreasing the amount of assistance according to the students' progress; (d) articulation, in which the teacher encourages students to articulate and clarify their knowledge and thinking; (e) reflection, in which the teacher allows students to compare their own thoughts, performance, strategies, and artifacts to those of experts and peers; and (f) exploration, in which the teacher gives students room to explore knowledge and use it in their own way to solve problems.

Some researchers have used cognitive apprenticeship models to enhance learning and teaching. For example, Collins et al. (1991) presented example cases to teach students thinking and mathematical problem-solving skills in mathematics and proposed that teachers must find strategies to render their expert mathematical problem-solving thinking and practical experience visible. Research has demonstrated that motivation and learning effectiveness increase as a result of the use of cognitive apprenticeship models of acquiring mathematical problem-solving skills through video modeling featuring a person demonstrating how to perform a task (e.g., Groenendijk et al. 2013; Hoogerheide et al. 2014; Van Gog et al. 2014). Additionally, the integration of cognitive apprenticeship and collaborative learning through video instruction can provide authentic situations in which students can easily explore the content of mathematical concepts and mathematical problem-solving strategies (Bransford and Vye 1989; Cobb et al. 1992).

To enhance the students' mathematical problem-solving skills via interest-driven video creation, this study used the six cognitive apprenticeship strategies as subcomponent concepts of the three components (*imitating*, *combining* and *staging*) of the creation loop model of IDC theory. The study used tutorial videos as expert models to explain and demonstrate how to solve mathematical word problems. Additionally, Collins et al. (1991) suggested that cognitive apprenticeship does not require that the teacher always play the role of the "expert" and that the roles of the expert and student can be switched. They also suggested that the teacher must provide opportunities and encouragement for students to become experts. Hence, in this study, students were asked to both teach their peers and act as apprentices to observe and compare with their peers with varying degrees of mathematical problem-solving skills and gradually form their own mathematical problem-solving skills.

Interest-driven video creation learning activity

This section describes the design of the interest-driven video creation learning activity, the learning process, and the supporting strategies in this study. The findings of a study by Kearney and Schuck (2005) revealed that the student-created videos task facilitated students' extrinsic interests (e.g., creating and presenting videos) and further extended their interests to the topic, so we adopted the interest loop model of IDC theory, which is composed of three components, namely, *triggering*, *immersing*, and *extending*, in a circular process to promote students' interest in a learning activity. Students' initial interest can be triggered by stimulating their curiosity. This goal can be achieved by emphasizing the relation between incoming new information and the students' existing prior knowledge, which will motivate students to learn the relation (Kong and Li 2016). To maintain students' interest, students must engage in a learning activity that allows full immersion, which requires a clear learning goal, feedback, and an appropriate challenge level of the task. To extend student interest, students must reengage with the learning activity so that they can integrate knowledge from different perspectives or include tasks that go beyond the current level. Hence, based on the interest loop model, in this study, the new idea of creating their own tutorial videos *triggered* students' initial interest. The new experience of indirectly teaching their peers through the creation of a video excited them and drew their attention. With the clear goal of creating videos and by maintaining an appropriate challenge level in the process through scaffolding, students became *immersed* in the activity. Finally, collaboration among peers provided the students with opportunities for reflecting, sharing, and integrating ideas, ultimately *extending* their ability to create videos and their mathematics knowledge.

The design of the learning activity, which was based on the creation loop model of IDC theory, included two types of creation activities: an individual creation loop and a group creation loop. Each creation loop contained three components: *imitating*, *combining,* and *staging*. The six cognitive apprenticeship strategies were adopted as subcomponent concepts of the three components of the creation loop model to support students' mathematics learning. According to this design, the students were encouraged to imitate others through observation to develop their initial ideas and knowledge and then to combine their own ideas with others' ideas to develop their own new knowledge, learning strategies or artifacts. Finally, the students were asked to present, demonstrate, and reflect on what they had created. When the students participated in a creative activity, their learning interest and domain knowledge were expected to be enhanced.

The interest-driven video creation learning activity follows a five-step learning process, and the steps of the learning activity and supporting strategies used in this study are shown in Table 1. The individual creation loop is composed of the first three activity steps (learning from tutorial videos, solving a similar problem, and sharing ideas) to help students to create their own concepts and mathematical problem-solving strategies. The group creation loop is composed of the last two activity steps (creating videos and demonstrating as a group) to help groups to collaboratively create their artifacts. Additionally, the scaffolding needed by the students is provided according to the various activity steps.

Learning from tutorial videos

In this step, students are provided with the learning resources in *imitating* (e.g., to acquire knowledge, students imitate someone or something by observing and adopting the learning resources to apply to the further learning process). A creator must have sufficient knowledge prior to creating, requiring the absorption of knowledge, i.e., the learning preparation needed to participate in creative activity. Additionally, knowledge can be gained by observing or learning from others. The cognitive apprenticeship strategy is adopted to facilitate students' acquisition of sufficient knowledge via *imitating*. Specifically, tutorial videos are provided as expert models for *modeling imitating* (e.g., students learn about specific behaviors, techniques, and work provided by the expert model through observation to help them to acquire knowledge). For example, tutorial videos present the actual problems that students encounter in the real world and then provide step-by-step explanations of how to solve the problem (e.g., "how to organize an argumentative essay"). Hence, this step provides students with the learning resources to help them to build rich background knowledge through observation and adoption to prepare to solve similar problems.

Solving a similar problem

In this step, students are given opportunities to integrate and use approaches employed in expert models to practice *imitating* (e.g., students apply the rules, methods, procedures, principles, strategies, and concepts that they learn to a new

Table 1 Interest-driven video creation learning activity and supporting strategies

Activity steps	Description	Component concepts of the creation loop model	Strategies of the subcomponent concepts
Learning from tutorial videos	Each student learns the concepts of a single topic, mathematical problem-solving skills, and how to create a video	Individual creation loop *imitating*	Students are provided with expert models for modeling in *imitating*
Solving a similar problem	Each student tries to solve similar mathematics word problems and writes down his/her own mathematical problem-solving process	Individual creation loop *imitating* *combining*	Students use approaches employed in the expert models to solve similar problems as their mathematical problem-solving strategies in *imitating* The teacher encourages students to solve problems in their own way through exploration in *combining*
Sharing ideas	Each student explains his/her own mathematical problem-solving process to his/her group members	Individual creation loop *staging*	Students explain their mathematical problem-solving strategies and processes to others through articulation in *staging* Students receive feedback and compare their mathematical problem-solving strategies and processes with others through reflection in *staging*
Creating videos	Each group organizes the context together to convey their own ideas and then creates their video	Group creation loop *imitating* and *combining*	Students collaboratively combine their mathematical problem-solving strategies, processes, and explanations to create tutorial videos in *imitating* and *combining* Group collaboration provides social scaffolding for creating videos in *combining*
Demonstrating as a group	Each group takes turns playing their video in the classroom The teacher encourages students' reflection and further explains whether something needs to be improved	Group creation loop *staging*	Each group demonstrates their tutorial videos in *staging* Students receive feedback and compare their mathematical problem-solving strategies, processes, and filmmaking techniques with others through reflection in *staging* The teacher further explains whether something needs to be improved through coaching in *staging*

situation). A new concept is formed by combining existing concepts, while a new artifact is created by combining existing concepts and artifacts. This step involves transforming or integrating existing concepts or artifacts to produce new concepts or artifacts (Knobel and Lankshear 2008; Lessing 2008; Liu et al. 2017; Chan et al. 2018). In other words, this step provides students with opportunities for *exploration* (e.g., students use their strategies applied in expert models to achieve a specific goal or complete a task that the teacher sets to improve their mathematical problem-solving) in *combining* (e.g., students generate their own new ideas or artifacts through transforming and integrating existing concepts and artifacts or imitating them to help them to achieve mastery in learning). Thus, this step provides students with a new learning situation, such as by asking them to solve similar problems or to draft storyboards (e.g., Ross et al. 2003), to help them achieve mastery after they have an understanding of what they have learned in the previous step.

Sharing ideas

In this step, each student is provided with a small stage in *staging* (e.g., students present or demonstrate their artifacts to an audience to foster a deeper understanding). This step provides students ample opportunities to communicate and present their creations for *articulation* in *staging* (e.g., to help students to be able to articulate their knowledge, reasoning, or mathematical problem-solving process that they have learned, students play the role of the master to explain their ideas or artifacts step by step to allow the other students, as the apprentices, to understand). Students obtain feedback through sharing with their peers, and they learn how to learn by teaching their peers (Chan et al. 2018; Nguyen 2013); in this way, the students can engage in *reflection* in *staging* (e.g., students compare their own ideas or strategies with those of experts or peers to reinforce their learning) by examining the similarities and differences between their work and others' work, allowing them to gain a deeper conceptual understanding and to improve the quality of their creations and facilitate their social gains. In brief, this step provides students with support to help them to organize their knowledge, share their ideas with group members, and prepare for the next step of the group creation loop.

Creating videos

In this step, the students are given more opportunities to discuss and collaborate with their group members, allowing them to learn through their peers in *imitating* (e.g., to prepare for video creation, students imitate their peers by observing and adopting their peers' ideas or strategies to apply to the later learning process). Additionally, students can collaboratively combine the knowledge that they have gained through sharing and collaboratively create videos as their artifacts in *combining* (e.g., students generate their own artifacts through transforming and integrating their existing concepts, strategies and artifacts to expand their knowledge). In addition, *social scaffolding* should be provided to prevent the students from not participating in group discussion and creation and to promote effective collaborative learning in *combining*; each student's individual accountability should be established to form positive, interdependent relationships (Chou and Lin 2015; Jensen et al. 2002; Johnson and Johnson 1994). For example, students in groups can take turns playing different roles (e.g., actor, camera operator, scriptwriter, and supporter) in creating videos in each activity; each student should be responsible for his/her own duties and assist other members in completing the task together. Hence, this step provides students with *scaffolding* to help them to collaboratively create their videos and to promote positive interdependence among students.

Demonstrating as a group

In this step, each group is provided with a large stage to present their artifacts to all of the students in *staging* (e.g., each group presents or demonstrates its artifacts to the other groups in the classroom). Each group member learns from the other groups' artifacts; receives feedback; and compares its mathematical problem-solving strategies, processes, and filmmaking techniques with others through *reflection* in *staging* to gain a deeper conceptual understanding (Chan et al. 2018). Additionally, students' reflection should be encouraged, and if something must be improved, the necessary improvement should be explained through *coaching* in *staging* (e.g., assistance that helps students to demonstrate, interact, and discuss with others in a way that they would otherwise be unable to do unassisted). Therefore, this step provides students with a stage for sharing their artifacts. As the audience expands, the students gain a sense of accomplishment and feelings of self-worth.

Evaluation

Research questions

The purpose of this study was to develop an interest-driven video creation learning activity and to evaluate students' mathematics learning achievement, attitudes, anxiety, and thoughts. Accordingly, the research questions were as follows:

1. How does an interest-driven video creation learning activity facilitate elementary students' math learning?
2. What are the high- and low-achieving students' attitudes and anxiety levels in participating in the student-created video activity?
3. What are the students' perceptions of the usefulness of mathematics and the learning activity based on their participation in the self-created video activity?

Participants and procedures

Twenty-one fifth graders (11.5 years old on average) at an elementary school in Taoyuan, Taiwan, participated in this study. Due to the equal opportunity education policy in Taiwan, the students were equally and randomly assigned to heterogeneous groups, each of which contained four to five members. All of the students already had experience using a tablet PC before the study. The authors trained students to use a tablet PC to create videos in a half-class session. Additionally, based on the students' midterm mathematics test scores, students with higher scores than the mean score were classified as high-score students, while students with lower scores were classified as low-score students. The classification was used only for activity grouping; and the students were not aware of the classification. The study procedures involved conducting two learning activities over a two-week period. Every student participated in a learning activity for 80 min (two regular class sessions) per week.

Learning environment, intervention preparation and intervention process

The student-created video learning environment is shown in Fig. 1. The authors prepared a total of 9 algebra tutorial videos as expert models. These videos were placed on a repository website and were accessible to the students from a tablet PC with an internet connection.

In the intervention preparation stage, the authors provided each group with a tablet PC, a microphone, a whiteboard, some colorful whiteboard magnets, a B4-sized sheet of paper, and different colored markers. The students could use these tools to create their videos. In addition, the authors equally and randomly assigned the students to groups, with each group containing four to five students; thus, there were five groups in total in the classroom. Figure 2 shows students using a tablet PC to create their instructional video. In each group, one student played the role of an actor being filmed, one student acted as a camera operator, one student acted as a scriptwriter who wrote down the mathematical problem-solving process, and one student (or two students, if there were five students in group) who acted as a supporter and provided the necessary support if the actor, camera operator, or scriptwriter students needed help. In addition, the students in each group took turns playing the different roles in each activity.

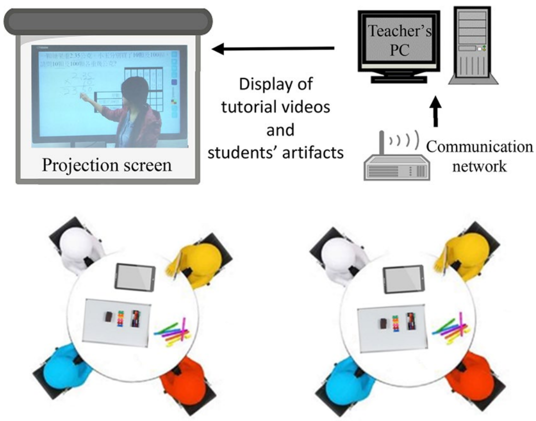

Fig. 1 Student-created video learning environment

For each learning activity, the authors provided students with three to four tutorial videos on the same single mathematics concept. After students watched the tutorial videos, four to five similar mathematics word problems were randomly assigned to each group to solve. The teacher encouraged the students to solve the problems in their own way. Thereafter, the group members took turns sharing their mathematical problem-solving processes with each other and discussed how to create their own videos. In the creating videos step, each group member used the built-in camera on the tablet PC to shoot his/her entire mathematical problem-solving process. After shooting the video, the students checked the quality of their videos, which were their artifacts, and then decided whether they needed to reshoot the video. In the demonstrating as a group step, the groups' artifacts were presented to the entire class with a projector. Each group took turns playing the final version of their artifacts, while the other groups spent time learning from the artifacts. Additionally, when each video was played, the teacher further explained aspects that needed to be improved and provided positive feedback on aspects that were done well.

Data collection

Mathematics achievement assessment

To measure the students' achievement in answering the first research question, a mathematics achievement assessment (in Chinese) was developed. The items were chosen from Taiwanese mathematics sources/supplementary algebra test books designed for fifth-grade primary school students. Additionally, the items were approved by two elementary mathematics teachers. The mathematics achievement assessment included 7 algebra word problem items, and the scores of the test ranged from 0 to 70 points. The fourth to seventh items were advanced problem items. Two parallel versions of the assessment were created that were administered before and after the intervention. The Cronbach's α values of the pretest and post-test assessments were 0.809 and 0.720, respectively. To analyze the assessment item discrimination, the highest and lowest 27% of the scorers were selected and grouped as high-achieving and low-achieving students, respectively. According to the findings of

Fig. 2 Student group using a tablet PC to create their tutorial videos

Kelley (1939), this procedure provides the optimal accuracy point for examining the significance of item criteria and groupings.

Table 2 shows the item discrimination and item difficulty. The item discrimination refers to the extent to which an item could distinguish the students' ability; the value was derived through a comparison of the numbers of high scorers and low scorers who answered the item correctly. The item difficulty is the difficultly level of an item for the students. For example, the difficulty of Item #1.3 was equal to (50% + 20%)/2 or 0.35. A higher difficulty value indicates that the item was easier to answer. The item discrimination and item difficulty values ranged from − 1.00 to 1.00. Additionally, both high- and low-achieving students' mean item accuracy rates for the post-test were higher than those for the pretest, and the difficulty values of the post-test were higher than those of the pretest, indicating that, overall, the students had made good progress at the post-test. The first four items discrimination values of the post-test were lower than the pretest values, meaning that the low-achieving students made greater progress than the high-achieving students on the first four items. However, the last three advanced problems were still difficult to answer for the low-achieving students.

Questionnaire

To assess the students' attitudes, anxieties, and perceived usefulness regarding the learning activity in response to the second research question, a 36-item Chinese learning experiences scale (Hung 2002), for which a Cronbach's alpha between 0.88 and 0.96 has been reported at elementary levels, was adopted and modified in this study. The modified questionnaire (38 items in Chinese) included four dimensions: attitudes toward the learning activity (10 items, Cronbach's $\alpha = .904$), perceived usefulness of mathematics (11 items, Cronbach's $\alpha = .938$), perceived usefulness of the learning activity (six items, Cronbach's $\alpha = .930$), and anxiety about the activity (eight items, Cronbach's $\alpha = .813$). The items were modified based on the academic needs of this study and were examined for their appropriateness for the research and elementary students by two elementary mathematics teachers. For example, the attitudes toward the learning activity dimension were used to measure the students' willingness to participate in the student-created video activity. A sample item from this dimension is "I was happy to participate in the student-created video activity." The perceived usefulness of the mathematics dimension was used to measure the students' beliefs regarding the usefulness of mathematics. A sample item from this dimension is "After participating in this activity, I found out what concepts I need to improve on." The perceived usefulness of the learning activity dimension was used to measure the students' beliefs regarding the usefulness of the student-created video activity. A sample item from this dimension is "Participation in the student-created video activity improved my communication skills." The anxiety about the activity dimension was used to measure the students' anxiety levels. A sample item for this dimension is "The learning activity made me feel stressed."

To evaluate the design of the five-step student-created video activity, 13 of the 38 questionnaire items were selected and classified into a dimension corresponding to

Table 2 Item discrimination and item difficulty for the pretest and post-test

Pretest					Post-test				
Item	% Correct high-achieving	% Correct low-achieving	Discrimination	Difficulty	Item	% Correct high-achieving	% Correct low-achieving	Discrimination	Difficulty
1.1	75	17.1	.579	.4605	2.1	100	92.9	.071	.9645
1.2	58.3	17.1	.412	.377	2.2	100	85.7	.143	.9285
1.3	50	20	.30	.35	2.3	100	78.6	.214	.893
1.4	66.7	20	.467	.4335	2.4	100	64.3	.357	.8215
1.5	41.7	0	.417	.2085	2.5	78.6	7.1	.715	.748
1.6	15	0	.15	.075	2.6	42.9	0	.429	.2145
1.7	3.3	0	.033	.0165	2.7	64.3	0	.643	.3215

one of the five steps: learning from tutorial videos (two items, Cronbach's $\alpha = .701$), solving a similar problem (two items, Cronbach's $\alpha = .863$), sharing ideas (five items, Cronbach's $\alpha = .893$), creating videos (two items, Cronbach's $\alpha = 0.891$), and demonstrating as a group (two items, Cronbach's $\alpha = .769$). For instance, the learning from tutorial videos dimension was used to measure the students' willingness to learn from the tutorial videos and how well the tutorial videos facilitated the students' learning. A sample item from this dimension is "I liked learning mathematics through watching the training videos." The Solving a similar problem dimension was used to measure students' beliefs regarding the usefulness of solving a similar problem. A sample item from this dimension is "Participation in the student-created video activity gave me a clearer understanding of different types of mathematics word problems." The sharing ideas dimension was used to measure students' beliefs regarding the usefulness of sharing ideas. A sample item from this dimension is "After participation in the student-created video activity, I had better knowledge of ways to improve my mathematical problem-solving ability for mathematics word problems." The creating videos dimension was used to measure students' beliefs regarding the usefulness of creating videos. A sample item from this dimension is "Through participating in the student-created video activity, I learned about other people's strengths and applied these to my group's video." The Demonstrating as a group dimension was used to measure students' beliefs regarding the usefulness of Demonstrating as a group. A sample item from this dimension is "Through participating in the student-created video activity, I compared my group's performance to that of the other groups in terms of the videos made."

The questionnaire had positive and negative items related to students' learning, and each of the items was scored on a five-point Likert scale ranging from "not at all true of me" to "very true of me" to indicate the student's degree of agreement with the statements. For the first three dimensions, the higher that the score was, the better that it was; for the last dimension (anxiety about the activity), the lower that the score was, the better that it was. The questionnaire was administered only at the end of the intervention. It took students approximately 40 min to complete the questionnaire. The students did not have any difficulty answering the questionnaire because it had no ambiguous items. Because one student was absent from school because of illness, 20 valid responses were obtained.

Learning feedback sheet

To explore the students' attitudes, anxiety, and thoughts about the learning activity in this study to answer the third research question, a learning feedback sheet with open-ended questions was used to obtain learning feedback from the students. The learning feedback sheet was provided at the end of the intervention and included two items. The first item was aimed at capturing students' attitudes toward creating and presenting videos about solving mathematical problems. The second item was aimed at determining students' perceptions of the benefits of creating the videos, especially in relation to mathematics learning and teamwork.

Data analysis

The first research question required the use of descriptive statistics and nonparametric tests to analyze the data (Pett 1997). All of the statistical tests were analyzed using the IBM SPSS program, version 22.00, with a significance level of .05. The quantitative data, including the mathematics achievement assessment scores and the scores of the five dimensions of the questionnaire, were analyzed with the means, standard deviations, the Mann–Whitney *U* test, and Wilcoxon's signed-rank test. For the second and third research questions, the scores on the four dimensions of the questionnaire were analyzed with the means, standard deviations, the Mann–Whitney *U* test, and Wilcoxon's signed-rank test. The qualitative data from the learning feedback sheet were presented in narrative form and classified according to the second and third research questions.

Results

Mathematics achievement assessment

The first research question focused on evaluating whether the five steps of the student-created video activity improved high-achieving and low-achieving students' mathematics performance; descriptive statistics were calculated, and nonparametric tests were conducted. The descriptive statistics of the students' pre- and post-test scores are presented in Table 3. The result shows that there was a statistically significant difference between the pretest ($M=16.81$, $SD=10.824$) and post-test ($M=46.67$, $SD=12.974$) scores.

Wilcoxon's signed-rank test was used to test the significance of the difference between pretest and post-test mean scores. Table 4 shows that the students' achievement scores after the intervention ($z_{(21)}=-4.017$, $p<.01$) were significantly higher than the students' scores before the intervention.

Table 5 shows that the high-achieving students' achievement scores after the intervention ($z(6)=-2.207$, $p<.05$) were significantly higher than the students' scores before the intervention.

Table 6 shows that the low-achieving students' achievement scores after the intervention ($z(7)=-2.375$, $p<.05$) were significantly higher than the students' scores before the intervention.

Table 3 Descriptive statistics of the students' pre- and post-test scores

Students	Total score	Pretest		Post-test	
		M	SD	*M*	SD
Total ($n=21$)	70	16.81	10.824	46.67	12.974
High-achieving ($n=6$)		30.67	8.066	52.50	13.323
Low-achieving ($n=7$)		7.43	1.512	44.29	12.392

Moreover, regarding the differences between the high- and low-achieving students, Table 7 shows the Mann–Whitney *U* test results of the difference in pretest scores between the high- and low-achieving students. Based on the Mann–Whitney *U* test results ($U < .001$, $p = .001 < 0.05$), there was a statistically significant difference by group.

Table 8 shows the Mann–Whitney *U* test results of the difference in post-test scores between the high- and low-achieving students. Based on the Mann–Whitney *U* test results ($U = 13.00$, $p = .243 > .05$), there was a minimal difference between the high-achieving and low-achieving students' post-test scores.

Table 9 shows the Mann–Whitney *U* test results of the difference in improvement from the pretest to post-test scores between the high-achieving and low-achieving students. Based on the Mann–Whitney *U* test results ($U = 11.00$, $p = .151 > .05$), there was a minimal difference in the average score improvement between the high-achieving and low-achieving students.

Questionnaire

The second research question focused on the students' interest in the student-created video activity, particularly with regard to their attitudes toward the learning activity and their anxiety about the activity. Additionally, the third research question

Table 4 Wilcoxon signed-rank test results of the difference between the pre- and post-test scores

Pre- and post-test measurements	*n*	Mean rank	Rank sum	*z*	*p*
Negative rank	0	0	0	– 4.017	0.000*
Positive rank	21	11.00	231.00		
Tie	0				

*$p \leq .001$, indicates a significant change from pretest to post-test

Table 5 Wilcoxon signed-rank test results of the difference between the high-achieving students' pre- and post--test scores

Pre- and post-test measurements	*n*	Mean rank	Rank sum	*z*	*p*
Negative rank	0	0	0	– 2.207	0.027*
Positive rank	6	3.50	21.00		
Tie	0				

*$p \leq .005$, indicates a significant change from pretest to post-test

Table 6 Wilcoxon signed-rank test results of the difference between the low-achieving students' pre- and post-test scores

Pre- and post-test measurements	*n*	Mean rank	Rank sum	*z*	*p*
Negative rank	0	0	0	– 2.375	0.018*
Positive rank	7	4.00	28.00		
Tie	0				

*$p \leq .005$, indicates a significant change from pretest to post-test

Table 7 Mann–Whitney *U* test results of the difference in pretest scores between the high- and low-achieving students

Students	*n*	Mean rank	Rank sum	*U*	*p*
High-achieving	6	10.5	63.00	.000	.001*
Low-achieving	7	4	28.00		

*$p \leq .001$, indicates a significant difference between the pretest scores of high- and low-achieving students

Table 8 Mann–Whitney *U* test results of the difference in post-test scores between the high- and low-achieving students

Students	*n*	Mean rank	Rank sum	*U*	*p*
High-achieving	6	8.33	50.00	13.00	.243
Low-achieving	7	5.86	41.00		

Table 9 Mann–Whitney *U* test results of the difference in the average score improvement between the high- and low-achieving students

Students	*n*	Mean rank	Rank sum	*U*	*p*
High-achieving	6	5.33	32.00	11.00	.151
Low-achieving	7	8.43	59.00		

focused on the students' perceptions of benefits from participation in the video activity, particularly with regard to the perceived usefulness of mathematics and the learning activity. The results of the questionnaire are shown in Table 10. One student was absent from school because of illness, resulting in 20 valid responses being obtained. For the first three dimensions of the questionnaire, the higher that the scores were, the better that they were; for the last dimension (anxiety about the activity), the lower that the score was, the better that it was.

All of the students who participated in the study had positive attitudes toward the learning activity. The mean subscale score was 4.33 (4.15 to 4.65). The item with the highest score was "I was happy to participate in this learning activity" ($M = 4.65$, $SD = 0.67$). The two items with the same lowest score (4.15) were "By watching the video tutorials, I was given the opportunity to fully learn the concept of mathematics" and "I am satisfied with my performance in this learning activity." The standard deviations for these two items were 0.87 and 0.93, respectively. Some of the comments from the learning feedback sheets are as follows.

- *S16* 「…The student-created video activity is a fun activity. It's also an interactive course that can improve your mathematics. It MIGHT also turn a "Mathematics Hater" into a "Mathematics Lover" or make one feel that mathematics has become easier.」
- *S03* 「When I did this activity for the first time, I felt so excited and thought that everything would go smoothly and end perfectly.」

Table 10 Results of the four dimensions of the questionnaire

Dimensions	Students	*n*	Mean value	Lower limit	Upper limit
Attitudes toward the learning activity	Total	20	4.33	4.15	4.65
	High-achieving	6	4.33	4	4.83
	Low-achieving	7	4.22	4	4.6
Perceived usefulness of mathematics	Total	20	4.26	4	4.45
	High-achieving	6	4.27	4.16	4.5
	Low-achieving	7	4.25	4	4.6
Perceived usefulness of the learning activity	Total	20	4.35	4.15	4.55
	High-achieving	6	4.36	4.16	4.66
	Low-achieving	7	4.5	4.4	4.6
Anxiety about the activity	Total	20	2.23	1	3.38
	High-achieving	6	2.14	1	2.88
	Low-achieving	7	2.05	1	3.25

- *S04* 「I think the best part is the feature of writing and drawing, as it allows you to try it [the feature] on different mathematics word problems. At least writing doesn't bore me; therefore, I found this class very meaningful and really enjoyed it.」
- *S02* 「If you record things while you are doing them, it will leave a deeper impression, and it is more interesting this way.」
- *S08* 「My favorite part is holding a tablet in my hand and solving the mathematics word problems. Because we get to record how our classmates explain the mathematical problem-solving process, I like helping them solve those mathematics word problems. I also help them when they encounter problems during their explanations, teaching them how to solve those mathematics word problems. After five practices, I believe everyone should be familiar by now.」
- *S07* 「Thanks for arranging such interesting activities this semester. Because our classmates seldom discussed mathematics together before participating in such activities, I think we will miss this last activity.」

Regarding the perceived usefulness of mathematics, the mean subscale score was 4.26 (4 to 4.45). The item with the highest score was "Participating in this activity helped my learning" ($M=4.45$, SD$=0.60$). The item with the lowest score was "After participating in this activity, I found that I was more focused in mathematics class" ($M=4$, SD$=0.91$). One of the comments from the learning feedback sheets was as follows.

- S06 「Dividing into groups and taking turns in recording the videos, knowing that there are many different ways of solving a mathematics word problem, and understanding the key to solving the mathematics word problems are the objectives of this activity to bring everyone to the next level.」

Regarding the perceived usefulness of the learning activity, the mean subscale score was 4.35 (4.15 to 4.55). The item with the highest score was "Participating in this activity improved my communication skills" (M = 4.55, SD = 0.60). The item with the lowest score was "Through participating in the student-created video activity, I shared with my group the positive points of the videos made by the other groups" (M = 4.15, SD = 0.98). Some of the comments from the learning feedback sheets are as follows.

- *S05* 「Since the mathematics word problems in the videos required us to discuss and work in groups, everyone participated and gave their full attention to avoid mistakes.」
- *S03* 「…There were a few times in the mathematical problem-solving process where we had some arguments, but we got that settled really soon; it's all about the skill to do "teamwork."」
- *S07* 「…The main activity is for students to discuss the process of solving mathematics word problems; everyone in the group has their own responsibilities, and you can't complete it if someone doesn't do it right, so teamwork is important here to complete this activity.」
- *S01* 「The student-created video activity not only taught me about the importance of teamwork but also allowed me to learn a variety of ways of solving mathematics word problems. It is really like killing two birds with one stone.」
- *S16* 「…It seems that everyone is not only learning mathematics but also learning how to work together with each other…」

Regarding learning anxiety, the mean subscale score was 2.23 (2 to 2.65). The item with the highest score was "I felt nervous when I learned through the activity" (M = 2.65, SD = 1.53). The item with the lowest score was "Learning through the activity did not make me feel confident and relaxed" (M = 2, SD = 1.07). There were some negative responses on the learning feedback sheets. For example, ten students stated that they felt shy when explaining the mathematical problem-solving process to others. Three students stated that they were embarrassed when demonstrating their group's artifact. Some of their narratives are as follows.

- *S13* 「One time, when it was my turn to explain the mathematics word problems, I got nervous. Although I encountered some difficulties, I finished recording in the end. However, when the teacher played the video, I felt very embarrassed, but this is what's fun.」
- *S18* 「I think the most memorable thing is to be in charge of explaining the mathematical problem-solving process because I got so shy when I was asked to explain; I really enjoyed this activity every single time.」

Table 11 shows the Mann–Whitney U test results of the differences in the scores on the four dimensions between the high- and low-achieving students. Based on the Mann–Whitney U test results ($p > .05$), there were minimal differences between the high- and low-achieving students' scores on the four dimensions.

To evaluate the five steps of the student-created video activity, i.e., learning from tutorial videos, solving a similar problem, sharing ideas, creating videos, and demonstrating as a group, the results for the five dimensions are provided (see Tables 12, 13, 14, 15, 16).

The results for this dimension revealed that 70% of the students answered Item #2 positively, while 5% of the students disagreed, and 25% of the students were neutral. For Item #4, 70% of the students answered positively, while 30% of the students were neutral. In the comments from the learning feedback sheets, twelve students reported that they had learned from tutorial videos and that the videos facilitated their learning (e.g., solving a mathematics word problem in different ways). Some of the students' narratives about how learning from the tutorial videos facilitated their learning are as follows.

- *S01* 「Watching videos does increase the ability to learn because sometimes a teacher teaching can be a bit unclear. Therefore, between choosing a teacher and tutorial videos, I would choose tutorial videos because that's why my mathematics is better.」
- *S06* 「Because sometimes, textbooks only provide one solution, and here, we are using different methods to solve a mathematics word problem. However, there are many ways to solve a mathematics word problem. Therefore, we get to learn about the different ways one can solve a mathematics word problem.」

The results for this dimension revealed that 80% of the students answered Item #7 positively, while 5% of the students disagreed, and 15% of the students were neutral. For Item #19, 80% of the students answered the question positively, while 20% of the students were neutral.

The results for this dimension revealed that 80% of the students answered Item #14 positively, while 20% of the students were neutral. For Item #11, 85% of the students answered it positively, while 15% of the students were neutral. For Item #12, 90% of the students answered it positively, while 10% of the students were neutral. For Item # 20, 95% of the students answered it positively, while 5% of the students were neutral. For Item #22, 75% of the students answered it positively, while 25% of

Table 11 Mann–Whitney *U* test results of the differences in the scores on the four dimensions between the high- and low-achieving students

Dimensions	Students	*n*	Mean rank	Mann–Whitney *U*	*Z*	*p*
Attitudes toward the learning activity	High-achieving	6	6.50	12.00	– .553	.580
	Low-achieving	7	5.40			
Perceived usefulness of mathematics	High-achieving	6	6.17	14.00	– .184	.854
	Low-achieving	7	5.80			
Perceived usefulness of the learning activity	High-achieving	6	5.75	13.50	– .300	.764
	Low-achieving	7	6.30			
Anxiety about the activity	High-achieving	6	6.17	14.00	– .185	.853
	Low-achieving	7	5.80			

Table 12 Students' attitudes toward the learning from tutorial videos step

Learning from tutorial videos ($n=20$)	Strongly disagreed (1)	Disagree (2)	Neutral (3)	Agree (4)	Strongly agree (5)
#2 I liked learning mathematics by watching the tutorial videos	0	1	5	2	12
#4 Learning by watching videos gave me ample opportunities to learn mathematical concepts	0	0	6	5	9

Table 13 Students' attitudes toward and perceptions of the usefulness of mathematics regarding the solving a similar problem step

Solving a similar problem ($n=20$)	Strongly disagree (1)	Disagree (2)	Neutral (3)	Agree (4)	Strongly agree (5)
#7 The student-created video activity gave me ample opportunities to practice mathematics word problems	0	1	3	5	11
#19 Participation in the student-created video activity gave me a clearer understanding of different types of mathematics word problems	0	0	4	5	11

the students were neutral. Some of the comments from the learning feedback sheets that noted that sharing ideas facilitated students' learning are as follows:

- *S02* 「…Everyone can share in groups, [and] sharing different methods of solving a mathematics word problem allows us to learn more efficiently.」
- *S04* 「I think this activity is a lot of fun because you can solve the mathematics word problems together with your classmates, enjoy doing mathematics, and at the same time, work together with them and learn their strong points from them.」

The results of this dimension revealed that 80% of the students answered Item #15 positively, while 20% of the students were neutral. For Item #18, 85% of the students answered it positively, while 15% of the students were neutral. One of the comments from the learning feedback sheets is as follows:

- *S03* 「…It was more enjoyable because during the last recording session; they applied mathematics to their acting.」

The results of this dimension revealed that 80% of the students answered Item #16 positively, while 20% of the students were neutral. For Item #17, 70% of the students answered it positively, while 5% of the students disagreed, and 25% of the students were neutral.

Discussion

This study aimed to develop an interest-driven video creation learning activity and evaluate students' mathematics learning achievement, attitudes, anxiety, and thoughts. The findings of this study are as follows:

Table 14 Students' perceptions of the usefulness of mathematics and the activity regarding the sharing ideas step

Sharing ideas ($n = 20$)	Strongly disagree (1)	Disagree (2)	Neutral (3)	Agree (4)	Strongly agree (5)
#14 Participation in the student-created video activity made my descriptions of the mathematical problem-solving process clearer	0	0	4	7	9
#11 Participation in the student-created video activity improved my communication skills	0	0	3	6	11
#12 Participation in the student-created video activity improved my voice and way of speaking when expressing myself	0	0	2	8	10
#20 After participation in the student-created video activity, I had better knowledge on ways to improve my mathematical problem-solving ability for mathematics word problems	0	0	1	7	12
#22 After participation in the student-created video activity, I had a better understanding of the areas that I needed to improve upon when solving mathematics word problems	0	0	5	4	11

Table 15 Students' perceptions of the usefulness of the activity regarding the creating videos step

Creating videos ($n=20$)	Strongly disagree (1)	Disagree (2)	Neutral (3)	Agree (4)	Strongly agree (5)
#15 Through participating in the student-created video activity, I learned about my classmates' methods of communication	0	0	4	6	10
#18 Through participating in the student-created video activity, I learned about other people's strengths and applied them to my group's video	0	0	3	5	12

Table 16 Students' perceptions of the usefulness of the activity regarding the demonstrating as a group step

Demonstrating as a group ($n=20$)	Strongly disagree (1)	Disagree (2)	Neutral (3)	Agree (4)	Strongly agree (5)
#16 Through participating in the student-created video activity, I compared my group's performance against that of the other groups in terms of the videos made	0	0	4	4	12
#17 Through participating in the student-created video activity, I shared with my group the positive points of videos made by the other groups	0	1	5	4	10

1. The interest-driven video creation learning activity facilitated elementary students' learning, especially their mathematical problem-solving abilities, communication skills, and filmmaking techniques.

The results of Wilcoxon's signed-rank test (Tables 4, 5, 6) of the mathematics achievement assessment revealed that there were significant differences in the pre- and post-test scores, indicating that the students' mathematical problem-solving abilities improved. Moreover, the Mann–Whitney *U* test results showed that there was a significant difference between the average pretest scores of the high- and low-achieving students (Table 7), indicating that a clear distinction existed between the high- and low-achieving students. However, the Mann–Whitney *U* test also revealed that there was a minimal difference between the average scores of the high- and low-achieving students (Table 8), indicating that the scores of the low-achieving students reached those of the high-achieving students after the intervention. Additionally, the Mann–Whitney *U* test results showed that there was a minimal difference in the average score improvements between the two groups (Table 9), indicating that both groups of students improved.

Additionally, the five-dimensional analysis of the student-created video activity using the questionnaire revealed that the students found the various steps useful in improving their mathematical problem-solving abilities, communication skills, and filmmaking techniques. More specifically, with regard to the individual creation loop, the Mann–Whitney *U* test results for the learning from the tutorial videos step (Table 12) revealed that most of the students liked learning mathematics by watching the tutorial videos and thought that the videos gave them opportunities to learn mathematical concepts. This finding is in line with the findings of studies (Choi and Johnson 2005, 2007; Mackey and Ho 2008; Pan et al. 2012) showing that tutorial videos have a nurturing value for instruction and can be provided to students for modeling and imitating. Based on the Mann–Whitney *U* test results for the solving a similar problem step (Table 13), most of the students reported that the student-created video activity gave them ample opportunities to practice similar problems and gave them a clearer understanding. The results indicate that students could explore the differences between the mathematics word problems in the tutorial videos and similar problems, use the approaches employed by the tutorial videos, and combine existing knowledge in their own way to solve similar problems and generate new mathematical problem-solving strategies**.** This finding is also in line with the creative process of changing from imitating to combining in the creation loop (Chan et al. 2018). The Mann–Whitney *U* test results for the sharing ideas step (Table 14) showed that most of the students believed that sharing ideas could improve their mathematical problem-solving and communication skills. More specifically, the students were provided opportunities to organize their mathematical problem-solving strategies, communicate their mathematical thinking to peers, and receive feedback on how to improve their mathematical problem-solving strategies in the sharing ideas step. This finding is consistent with the creative process of transitioning from combining to staging in the creation loop (Chan et al. 2018).

Regarding the group creation loop, the Mann–Whitney *U* test results for the creating videos step (Table 15) showed that most students reported that creating videos improved their communication skills and filmmaking techniques. More specifically, the students were provided with opportunities to collaborate, learn peers' mathematical problem-solving strategies and combine existing knowledge in their own way to create their tutorial videos as their artifacts. This finding is also in line with the creative process of transitioning from imitating to combining in the creation loop (Chan et al. 2018). Based on the Mann–Whitney *U* test results for the demonstrating as a group step (Table 16), most of the students compared and shared their mathematical problem-solving strategies, processes, and filmmaking techniques with others. More specifically, each group shared its artifacts for staging, received feedback from other groups, and then compared its artifacts and filmmaking techniques for reflection. This finding is consistent with results regarding the development of a deeper understanding and sense of knowledge in the creation loop (Chan et al. 2018).

Notably, based on the IDC theory framework, which incorporates six cognitive apprenticeship strategies as subcomponent concepts of the creation loop model, learning from creating videos and sharing ideas can be considered forms of learning by teaching. When students know that they will prepare to teach their fellow classmates by creating videos, they will organize their knowledge better, hence improving their learning and engaging in careful practices (Bargh and Schul 1980; Psaradellis 2014). Moreover, when students explain their mathematical thinking to others, the process enables them to improve their comprehension of mathematics content (Falchikov 2001) and allows them to learn more deeply (Hanke 2012; Jacq et al. 2016). The findings of this study also show how video creation can increase both students' interest and their learning.

2. Both high- and low-achieving students had positive attitudes and low anxiety toward participating in the interest-driven video creation learning activity.

The results from the four dimensions of the questionnaire (Table 10) and the learning feedback sheets revealed that the students' mathematics learning attitudes toward the student-created video activity tended to be positive and that their anxiety levels about the activity tended to be low. Additionally, the results of the Mann–Whitney *U* test showed minimal differences in attitudes between the high- and low-achieving students (Table 11). This finding indicated that the interest-driven video creation learning activity could increase both high- and low-achieving students' interest. Regarding attitudes toward the learning activity, the students seemed to be satisfied with the video creation activity; they enjoyed it and were happy with it and interested in it as a mathematics learning activity. These findings were consistent with the results of previous similar student-created video studies (e.g., Hulsizer 2016; Kearney and Schuck 2005; Banaszewski 2002). Additionally, the learning feedback sheets revealed that the students enjoyed the video creation learning activity and were especially impressed by sharing, collaborating with peers in small groups, communicating mathematics concepts with peers, and creating their artifacts with the tablet PCs. These responses might have occurred due to the activity being interactive and the free communication in small groups, which made the learning experience quite different from traditional approaches. Regarding anxiety about the activity, the results from Table 10 indicate that the students' anxiety levels were low when participating in this activity. Additionally, the results of the Mann–Whitney *U* test showed minimal differences in anxiety between the high- and low-achieving students (Table 11). This finding indicated that both high- and low-achieving students' anxiety levels were low when participating in this activity. However, the standard deviation for the item with the highest score was higher than that of the other items, suggesting that some students might feel nervous when performing this activity. On the learning feedback sheets, 10 students mentioned that they felt embarrassed when they played the role of an actor to explain their mathematical problem-solving processes or were asked to show their videos in front of their peers. This finding is in line with the findings of a study by Martin et al. (2013) showing that students sometimes felt nervous when they were in front of a camera or heard their own voices. Moreover, this embarrassment could be one of the reasons for a number of students' anxiety scores being higher than the mean scores. Nevertheless, the findings of a study by Kearney and Schuck (2006) indicated that creating a video generated less anxiety than giving an oral class presentation.

3. Both high- and low-achieving students perceived both mathematics and the learning activity to be highly useful based on their participation in the interest-driven video creation learning activity.

The results from the four dimensions of the questionnaire (Table 10) revealed that the students' perceptions of the usefulness of mathematics and the learning activity tended to be positive, and all of the students gave positive feedback on the learning feedback sheets. Additionally, the results of the Mann–Whitney *U* test showed minimal differences in the perceived usefulness of mathematics and the learning activity between the high- and low-achieving students (Table 11). These results indicated that the high- and low-achieving students had positive opinions of the activity's usefulness and found the activity to be useful for learning mathematics. Additionally, the comments from the learning feedback sheets revealed that some students recognized the importance of teamwork and that each member needs not only to concentrate on the work for which he/she is responsible but also to make concerted efforts to complete the work. In addition, the students learned to establish positive individual accountability and form positive interdependence relationships when they took turns playing different roles in each learning activity. For example, one student mentioned that, when his classmate who was playing the actor role encountered difficulties, he helped his classmate and taught him how to solve the problem.

Regarding the perceived usefulness of mathematics, students believed that the learning activity improved their mathematical problem-solving abilities and helped them to understand mathematics curriculum materials and related concepts. This finding was also in line with the findings of studies by Rodriguez et al. (2012), Yang and Wu (2012), and Jordan et al. (2015), in which student-created video activities likely helped students to improve their academic performance. Regarding the perceived usefulness of the learning activity, the results from the questionnaire and the learning feedback sheets revealed that most of the students believed that the student-created video activity improved their communication skills, teamwork skills, and filmmaking techniques. This finding was also in line with the findings of studies by Kearney and Schuck (2006).

Implications and future work

In this study, an interest-driven video creation learning activity was developed to support both high- and low-achieving students' interest and learning. Several characteristics of the learning activity warrant emphasis. First, the learning activity is interest-driven. Based on the interest loop in IDC theory, the student-created video activity is intended to stimulate students' curiosity. Tutorial videos are used to trigger students' initial interest to provide them with new knowledge and problems beyond their levels. To maintain students' interest and to fully immerse them in the learning activity, this activity provides students with the scaffolding of individual and group learning processes to support them in establishing a goal and creating tutorial videos as their artifacts. To extend students' interest in gaining more knowledge and to guide them to repeat this learning experience, the activity provides students with opportunities to integrate knowledge from discussions, sharing of ideas, and reflections with peers to ultimately create their own unique works. The findings from this study show the preliminary positive results that the interest-driven video creation learning activity facilitated students' mathematical problem-solving abilities, communication skills, and filmmaking techniques. Both high- and low-achieving students showed positive attitudes and low anxiety, and they perceived both mathematics and the learning activity to be highly useful based on their participation in the interest-driven video creation learning activity. Second, the preliminary positive results from this study showed that high- and low-achieving students can collaboratively work and share ideas by heterogeneous grouping. Students in groups learn strong points from their group members, take turns playing different roles in each activity, make themselves responsible for their own duties and assist group members in completing the task together. Third, the learning procedures for individual and group learning are flexible. Educators and researchers can apply, modify, and extend this activity with existing technology support in a variety of academic fields to support students' interest and learning. For example, in this study, the tutorial videos as expert models and students' artifacts were stored on a private repository website. Educators and researchers can use YouTube as a storage platform (e.g., Majekodunmi and Murnaghan 2012). The study uses tablet PCs as the students' creative tools. Educators and researchers can use smart phones for video creation (Benedict and Pence 2012). In addition, the types of student work that can be created are not limited to videos but can be replaced by different media, for example, podcasts (Fredenberg 2008; Armstrong et al. 2009) and blogs (Benedict and Pence 2012). Moreover, the content of student work is also not limited to video instruction; it can be replaced by other content, such as acting (Ross et al. 2003) and storytelling (Shelton et al. 2017). Fourth, this paper represents an example of the early application of IDC design. The design of the video creation activity includes individual and group creation loops and the use of cognitive apprenticeship strategies as subcomponent concepts of the creation loop in IDC theory for video creation. The findings from this study provide preliminary positive results for mathematics achievement to support IDC design. Finally, Greene (2014) claimed that almost any classroom topics are suitable for video creation. This study also reviews and introduces the various learning topics and tasks of student-created video activities. Furthermore, the appropriate topics and tasks that provide opportunities for students to develop their creativity and reflection are suitable to assign to them for video creation, such as providing the problems that require procedural and multiple solutions (e.g., Cai and Kenney 2000) and conceptual knowledge that can be interpreted, demonstrated, and represented in different ways (e.g., Greene 2014).

Nevertheless, in order to develop students' learning habits, students must be provided with routine creative learning activities to promote their self-directed capability to learn, reflect, and reach a specified learning goal (e.g., to produce specific knowledge, learning strategies, or artifacts) naturally as a habitual behavior. Ultimately, completing the goal will produce the positive psychological rewards (e.g., a sense of confidence, satisfaction, achievement, pride, self-worth, enjoyment, or interest) that students seek. Additionally, interest is a long-term preference for certain activities or domains of knowledge (Bergin 1999); it is necessary to maintain students' learning attitudes to nurture their interest in learning. Future studies should continue to assess the long-term effects of such activities on interest and achievement. Further research with larger samples and more academic concepts should be conducted. In addition to gathering more data on students' learning concepts and acquisition, it would be interesting to analyze students' artifacts and explore the degrees of learning between the different group roles, from script writer to camera operator to actor, and in relation to other appropriate topics and concepts to increase the generalizability of the study.

Limitations of the study

This study had two limitations: the sample size was small, which means that the generalizability is limited; and the students participated in the activity only five times in two weeks, so the findings from this study cannot be generalized to assess the depth and breadth of learning. Nevertheless, the present study articulates and enriches the creation loop model of IDC design in mathematics and contributes to an understanding of the preliminary and potential benefits of student-created video activities for mathematics learning.

Conclusion

This study developed an interest-driven video creation learning activity by adopting the creation loop model of IDC theory and incorporating six cognitive apprenticeship strategies as subcomponent concepts of the creation loop model to support students' mathematics learning. This interest-driven video creation learning activity includes individual and group creation loops that comprise five steps, i.e., learning from tutorial videos, solving a similar problem, sharing ideas, creating videos, and demonstrating as a group, to provide flexible and scalable procedures for supporting students' interest and learning. This study found statistical evidence that the interest-driven video creation learning activity resulted in significant improvements in mathematics achievement. Additionally, the quantitative questionnaire data and qualitative feedback indicated that both high- and low-achieving students had positive attitudes and low anxiety regarding the activity and perceived mathematics and found the learning activity to be highly useful. Students showed greater engagement and involvement in the activity than in traditional teaching methods. It could be concluded that there was positive evidence of the effectiveness of the elementary program. Although the use of student-created video activities for elementary mathematics learning is a relatively new educational approach, it has the potential to be effective in improving students' learning and engagement.

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