Journal of Pedagogical Research
Volume 8, Issue 2, 2024
https://doi.org/10.33902/JPR.202425017

Research Article

The effect of 7E learning cycle enriched with computer animations on students' conceptual understanding and overcoming misconceptions

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While computer animations have the potential to assist learners in understanding difficult concepts and eliminating misconceptions, studies supporting this claim are scarce. This study investigated how the 7E instructional model integrated with computer animations affected students' conceptual understanding and misconceptions about food making and plant growth. Experimental groups were taught the 7E learning cycle model [7E LCM], and 7E LCM with computer animation [CA] while the control group was taught the conventional instruction method. A two-tiered conceptual understanding multiple-choice test and semi-structured interviews were used to collect the data. ANOVA analysis revealed no significant differences between groups or genders in pre-food making and growth in plant conceptual understanding [pre-FMGPCU] and pre-misconceptions test scores [pre-MC]. There were, however, significant differences in post-FMGPCU and post-MC mean scores, with the 7E LCM with CA showing better results in improving conceptual understanding and minimizing misconceptions. MANOVA revealed no statistically significant difference between male and female students' post-FMGPCU and post-MC results. It was concluded that the 7E LCM with CA enhances students' conceptual understanding and minimizes misconceptions more effectively than other instructional approaches. It is recommended that similar designs be used in biology teaching.

Keywords: Conceptual understanding; Computer animation; Food making and Growth in plants; Misconceptions; 7E learning Cycle Model

Article History: Submitted 24 November 2023; Revised 26 March 2024; Published online 12 May 2024

1. Introduction

The most important goal of almost every country's national curriculum is to promote a meaningful understanding of scientific concepts. The achievement of this goal requires the active engagement of students in the learning process (Olimpo & Esparza, 2020). In addition, students must be provided with opportunities to relate the new concepts to their prior knowledge and use their new conceptual understanding to explain the experiences they encounter (Kayii & Akpomi, 2022; Shah Ph & Kumar, 2019). Since learners may come into the learning environment with views or ideas that are incorrect in relation to what the teacher must teach. Several concepts in science are difficult

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How to cite: Mekonnen, Z. B., Yehualaw, D. D., Mengistie, S. M., & Mersha, B. S. (2024). The effect of 7E learning cycle enriched with computer animations on students' conceptual understanding and overcoming misconceptions. *Journal of Pedagogical Research, 8*(2), 325-356. https://doi.org/10.33902/JPR.202425017

for students to understand, causing them to experience misconceptions (Soeharto & Csapó, 2021). If misconceptions are not discovered and overcome, they become part of students' cognitive structures and interfere with their subsequent learning process. In order to prevent the occurrence of rote learning, conscious linking of new knowledge to relevant concepts they already possess is required (Ausubel et al., 1968). Students who frequently use rote learning tend to generate misconceptions concerning scientific concepts (Dogru-Atay & Tekkaya, 2008; Galvin & O'Grady, 2014; Vosniadou, 2020). So, the type of instruction method for promoting meaningful learning and eliminating misconceptions is very important.

Biology has special relevance to students as individuals, to society, and to the growth and development of a country at large. However, some topics are considered difficult for some students. Many concepts or topics in biology, including water transport in plants, protein synthesis, respiration and photosynthesis, gas exchange, energy, cells, genetics, organs, and the central nervous system, can be perceived as difficult to learn and understand by students(Fauzi & Mitalistiani, 2018). As a result, students' difficulties with many topics in biology have prompted researchers to investigate why students have such difficulties and how to overcome these difficulties.

Research studies showed that by using a traditional instruction approach, most teachers have difficulty diagnosing their students' learning problems or misconceptions (Soeharto & Csapó, 2021). However, constructivist teaching methods take into account students' prior knowledge at the start of the learning process and lead to meaningful learning with a deep understanding of concepts (Behera, 2019). Constructivism as a theory of learning factors prior knowledge as the main basis for construction of new knowledge (Geofrey, 2021).

The learning cycle has been identified as one of the most prevalent constructivist teaching approaches that promotes learning through hands-on and mind-on activities. Different learning models are presented by research scholars, which improved students' learning skills over a period of 3E, 4E, 5E, 7E, and 9E (Saad et al., 2023). The 7E Learning Cycle Model is organized in seven successive stages. These stages are: elicit, engage, explore, explain, elaborate, evaluate, and extend (Eisenkraft, 2003). The learning cycle emphasized that learning should start with (1) eliciting the prior knowledge of the learners; (2) engaging the learners by using a discrepant event to arouse their interest; (3) exploring the skills and knowledge of the students; (4) explaining the new concepts by allowing students to verbalize and clarify the concept; (5) elaborating the newly learned concepts of the students through questioning; (6) evaluating the learning outcome of the students through the use of formative assessment; and (7) extending the knowledge by helping students to connect the concept to different contexts; or transfer the knowledge to other contexts (Abdullahi et al., 2021; Eisenkraft, 2003).

Several studies have been carried out on the effectiveness of constructivist teaching approaches on students' learning. The studies about the instructions based on the learning cycle model showed that learning cycle approaches help students improve academic achievement (Khan et al., 2020); self-efficacy (Puspita & Fardillah, 2021); critical thinking skills (Marfilinda et al., 2020; Tecson et al., 2021); retention (Abdullahi et al., 2021; Wodaj & Belay, 2021); science process skills (Khairani et al., 2021; Komikesari et al., 2020; Silitonga et al., 2021) and attitudes toward science (Abdullahi et al., 2021; Ören & Tezcan, 2020).

A substantial body of research on learning cycle approaches has demonstrated their effectiveness on conceptual understanding (Baybars & Kucukozer, 2018; Gök, 2014; Komikesari et al., 2020; Yilmaz et al., 2011). For example, Gök (2014) investigated the relative effects of 7E learning cycle instruction and curriculum-oriented science instruction on middle school students' conceptual understanding of human body systems in Turkey. The experimental group students learned the skeletal system, circulatory system, and respiratory systems topics through 7E learning cycle instruction, while the comparison group students received curriculum-oriented science instruction. The results of the study showed that 7E learning cycle instruction was found to be more effective than curriculum-oriented science instruction in terms of acquiring conceptual understanding. Similarly, Baybars and Kucukozer (2018) examined the effect of the 7E Learning Model on the conceptual understanding of prospective science teachers in Turkey. The study used a pretest-posttest design and found that the model improved teachers' conceptual understanding of de Broglie's matter waves, leading to more alternative concepts. Komikesari et al. (2020) also investigate the effect size test of the 7E learning cycle model on conceptual learning in senior high school students in Bandar Lampung. The research method used was a quasi-experiment with a non-equivalent control group design. Their finding indicates that the application of the 7E Learning Cycle Model is more effective in improving conceptual understanding than conventional instructional methods.

Technology has the ability to transform many aspects of science classroom instruction. The use of technology in learning and teaching environments provides students with a richer learning environment, stimulates interest, provides lesson motivation, and helps students remember information about previously taught topics (Oliver, 2000). As the need for a scientifically and technologically literate society increases, the relationship between science and technology in the context of learning has increasingly become a focus of reform in science education(Reid-Griffin & Carter, 2004). The infusion of technology in pedagogy improves learning, motivates and engages learners, promotes collaboration, promotes inquiry and exploration, and creates a new learner-oriented learning culture (Thakur & Raghuwanshi, 2016). Computer animation is one of the technologies being utilized widely in science education. It was found that computer animations have two basic functions, namely, an enabling function and a facilitating function(Liu & Elms, 2019; Schnotz & Rasch, 2008). The enabling function allows processes to be made possible due to reduced cognitive load, while the facilitating function reduces mental effort required for existing processes. Urhahne et al. (2009) also highlighted the potential benefits of dynamic representations like three-dimensional animations in providing visual explanations for scientific phenomena, potentially reducing cognitive load, and supporting active learning.

It is widely acknowledged that many theoretical concepts in physics, chemistry, and biology are difficult for students to grasp and about which they have misconceptions. It is also known that students do not, or only rarely, apply what they learn in those sciences in their daily lives (Özmen et al., 2000). In many of these cases, it was stated that in the education and learning process, the inadequate traditional education system and the existing educational materials are neither helping to solve the existing problems nor assisting in the development of conceptual learning(Gönen et al., 2006). Due to its positive effect on increasing the attention and curiosity of students and the help it provides in conceptual learning, the use of computers in education is spreading widely (Gönen et al., 2006). Computer-aided animations can help students understand education concepts, particularly in concretizing abstract ideas (Ala et al., 2023; Aydin et al., 2022; Putro et al., 2021. For example, a study by Ala et al. (2023) found that computer-animation strategies improved students' academic performance in biology concepts in Bauchi State, Nigeria compared to traditional methods. Furthermore, because most knowledge about natural phenomena is now available in a computer environment, teachers who use computers as a teaching tool will be able to show physical phenomena in a way that students can visualize in three dimensions (Gönen et al., 2006).

Few studies have been conducted to assess the effectiveness of integrating computer animations into the 7E learning cycle on student learning (Bülbül, 2010; Celik et al., 2013; Gönen et al., 2006; Kencana et al., 2020; Kocakaya & Gonen, 2010; Miadi et al., 2018; Sarac & Tarhan, 2017; Warliani et al., 2017). Their research findings indicated that 7E LCM supported by computer animation was more effective than conventional instructional models in improving students' conceptual understanding, science process skills, and attitudes towards science. For instance, Bülbül (2010) compares the effectiveness of the instruction based on the 7E learning cycle model accompanied with computer animations and traditionally designed biology instruction on 9th grade students' understanding and achievement related to diffusion and osmosis concepts. A quasi-experimental design was used in this study. The results indicated that instruction based on the 7E learning cycle model accompanied by computer animations caused significantly better acquisition of the scientific concepts related to diffusion and osmosis than traditionally designed biology instruction.

The other major issue in science education in recent decades has been gender. There have been conflicting findings on gender differences in achievement in science subjects. Many studies have also shown that male students achieve higher than their female counterparts in science, while some show no significant gender influence on students' achievement in science (Dogru-Atay & Tekkaya, 2008; Okafor & Okewale, 2016; Shaheen & Kayani, 2015). For example, Nzewi (2010) reported that more female than male students had difficulties and held misconceptions in senior secondary school science. On the other hand, Bülbül (2010) demonstrated that there were no statistically significant mean differences in posttest mean students' biology conceptual understanding scores between male and female students. Research also revealed that the female students left the male students behind when seen from the perspective of attitude toward science (Dhindsa & Chung, 2003; Shaheen & Kayani, 2017).

Most of the published research on the 7E inquiry model of instruction is done in developed countries, whose contexts are different from those in developing countries. Few studies have been done in Africa in line with the effectiveness of 7E instructional models (Abdullahi et al., 2021; Cherono et al., 2021; Gyampon et al., 2020; Naade et al., 2018; Shuaibu & Ishak, 2020; Wodaj & Belay, 2021). For instance, Cherono et al. (2021) examined the effect of the 7E learning cycle model on students' academic achievement in biology in secondary schools in Kenya. The study showed that the 7E learning cycle model is an effective way of improving students' academic achievement in biology. Wodaj and Belay (2021) also investigate the effect of the 7E instructional model with metacognitive strategies on students' learning biology and motivation compared to conventional instruction in biology in secondary schools in Addis Ababa, Ethiopia. They found that the 7E instructional model with metacognitive strategies was better than conventional instruction at improving students' achievements, conceptual understanding, and retention of concepts in learning biology. Additionally, 7E instructional model with metacognitive strategies effectively reduced students' misconceptions compared to conventional methods. However, no significant differences were found between male and female students in posttest scores or an interaction effect between treatment and gender.

The Ethiopian education and training policy emphasizes a constructivist-based, learner-centered approach that employs various active learning strategies rather than the traditional chalk and talk manner of delivery (Ministry of Education [MOE], 2002). Modern teaching methods recognize that there is a need to give students the chance to think about what they are being taught or what they are learning. This means that teachers must not spend entire lessons talking but instead plan opportunities for class discussions in which students can exchange ideas, resolve misunderstandings, and make sense of what they are hearing, or engage in a variety of different activities that allow them to construct meaning for themselves out of the information they are receiving. This approach is based on the constructivist theory of teaching and learning, which underpins the concept of competency-based education. Furthermore, the policy was designed to address the use of digital technology for quality improvement. Following the policy, many achievements have been made in terms of enrollment, equity, and access to education. However, the problems of quality of education in general and relevance of curriculum development and implementation in particular are still visible in the country's education system. For example, the implementation of the concept of this general idea stated in the figure in the classroom is not easy. Ethiopian research shows low teachers' understanding and skills in implementing learner-centered techniques in biology classes, with traditional lecture methods dominating classrooms(Beyessa, 2014; Teshome, 2012). Additionally, there were also gaps in addressing the integration of ICT and pedagogy to enhance the quality of education and maximize students' learning (MOE, 2021). Therefore, the current country's education and training roadmap for 2018–2030 is designed to strongly address the gaps in the previous issues (MOE, 2021).

Similarly, the national learning assessment and examination results of the students in the country are not promising (National Educational Assessment and Evaluation Agency [NEAEA], 2022). The overall score of students was found to be far below the standard: more than 50 percent of students have achieved below 50 points (with a mean score of 38 by Grade 8, 47 by Grade 10, and 45 by Grade 12 students) (NEAEA, 2022). Looking at the mean score for biology in Grade 10, the mean score (40.3%) was below the minimum requirement (50%). Benishangul Gumuz is one of Ethiopia's three lowest-performing regions in terms of achievement (NEAEA, 2022). Researchers linked the regular poor academic achievement of majority students to the inability of teachers to apply effective instructional approaches while teaching (Ikedolapo & Adetunji, 2009; Wodaj & Belay, 2021; Zakaria & Iksan, 2007). The researcher also noticed that teachers' use of inquiry-based biology teaching is very limited in the study area. Most school teachers favor the traditional teaching approach for teaching biology concepts, which rewards learners' ability to reproduce facts without truly understanding the topic and predictably fails in the face of the complex interactions involved in biology(Schmid & Telaro, 2018; Woldeamanuel et al., 2020). In addition, teaching methods are not supported by technology for teachers' facilitation roles in knowledge construction and development. This might be the possible reasons for the low learning assessment results of students in biology in the study area. Therefore, there is a real need to search for effective learner-centered instructional approaches that would help learners learn biology better and improve their performance in the Ethiopian context.

The topic "food making and growth in plants" was used in the present study because it is one of the topics indicated in the MoE (2010) report for grade 10 biology that should be taught and tested comprehensively as well as broadly to bring the students on board with critical issues of the 21st century. Learning about food production and plant growth is critical for students because it is a fundamental concept in biology that they must understand before moving on to the next level. If the students do not understand this concept, it will be difficult for them to understand the next concept about plants. It needs a way to overcome difficulties since the concept is important for the students. The way that students can learn plants easily is by having an understanding of them. The students who have mastered the concept will be able to remember it, which has been learned over a long period of time to make the learning meaningful (Choirina et al., 2019).

A few studies examining how well students understood food production and growth in plants indicated that students had a considerable degree of misconceptions in various grade levels, and these misconceptions were resistant to change by traditional teaching methods (ALkhawaldeh, 2019; Balci et al., 2006; Choirina et al., 2019; Chuenmanee & Thathong, 2017; Galvin et al., 2015; Griffard & Wandersee, 2001; Lin, 2004; Marmaroti & Galanopoulou, 2006; Parker et al., 2012; Skribe Dimec & Strgar, 2017; Vitharana, 2015; Woldeamanuel et al., 2020). Furthermore, most of the teachers have difficulty diagnosing their students' learning problems or misconceptions in the study area.

Several studies suggest that 7E instructional models and computer-based instruction improve biology learning (Bülbül, 2010; Celik et al., 2013; Eshetu et al., 2022; Gönen et al., 2006; Kocakaya & Gonen, 2010; Miadi et al., 2018; Sarac & Tarhan, 2017; Warliani et al., 2017; Wodaj & Belay, 2021). For example, Bülbül (2010) compares the effectiveness of the instruction based on the 7E learning cycle model accompanied with computer animations and traditionally designed osmosis and diffusion topic instruction on students' conceptual understanding in Istanbul. The results indicated that instruction based on the 7E learning cycle model accompanied by computer animations significantly improved students' conceptual understanding and minimized misconceptions. Similarly, Warliani et al. (2017) and Miadi et al. (2018) studied the effectiveness of the 7E Learning Cycle using TBCT (technology-based constructivist teaching) on students' conceptual understanding of mechanical wave material and static fluid concepts in Indonesia, respectively. Eshetu et al. (2022) investigated the effects of a technology-integrated guided inquiry-based approach on pre-service mathematics teachers' conceptual understanding of geometry when compared to a guided inquiry approach and a traditional teacher-centered approach in the

Oromiya region of Ethiopia. Their findings showed that a technology-integrated, guided inquiry-based approach showed a greater level of conceptual understanding. Wodaj and Belay (2021) also investigate the effect of the 7E instructional model with metacognitive strategies on students' understanding and misconceptions in human biology contents conducted in four government schools in the capital city, Addis Ababa. Their findings showed that the 7E instructional model supported by metacognitive strategies was significantly superior to conventional instruction for improving students' conceptual understanding of concepts in learning biology and minimizing misconceptions. As a result, this research can be conducted in different regions, topics, metacognitive strategies, and grade levels to increase the generalizability of the conclusions.

To summarize, the type of instruction method for promoting meaningful learning and eliminating misconceptions is very important. Therefore, there is a need to explore a change in teaching strategy from the conventional method to a computer-based, multimedia-supported one and see its effect on students' conceptual understanding of biology. After conducting a literature analysis, no research studies were found on the effectiveness of the 7E Learning Cycle model with computer animation on students' conceptual understanding and misconceptions in secondary school in Ethiopia. In this study, the 7E learning cycle model integrated with computer animations that facilitate students' learning by visualizing processes related to food production and growth in plant concepts, was designed and implemented. The investigation made an effort to address the following research questions: i) Is there a significant mean score difference in food making and growth in plant conceptual understanding among students instructed by the 7E learning model, the 7E LCM with CA, and the conventional instructional method? ii) Is there a difference in misconceptions among students who will be taught the content "food making and growth in plants "using the 7E learning model, 7E LCM with CA, and conventional instructional methods? iii) Is there a significant mean score difference in biology conceptual understanding and misconceptions between male and female students taught using the 7E learning model, 7E LCM with CA, and conventional instructional methods?

2. Method

2.1. Research Approach

The purpose of this study was to investigate the effect of the 7E instructional model integrated with computer animations on students' food making and plant growth conceptual understanding and their misconceptions. To achieve the purpose of the study, a mixed research approach was used. The study used a two-tier conceptual understanding multiple-choice test to assess students' conceptual understanding and misconceptions quantitatively. A two-tiered multiple-choice test, in which the first item is a fact-based question and the second item is a reasoning-based question, permits higher-order thinking skills to be evaluated (Gero et al., 2019). However, it was found that only quantitative methods may not be sufficient, so a qualitative approach, such as semi-structured interviews, was employed to gain detailed information on students' understanding.

2.2. Research Design

In this study, the nonequivalent pretest, multiple treatments, and posttest control group quasi-experimental research design (Creswell, 2009) was used. The design has one comparison group and two treatment groups, with a pretest and a posttest. The students in the experimental groups were instructed in 7E learning cycle model integrated with computer animation and 7E learning cycle model whilst those in the control group were instructed on the same concept through conventional approach. Accordingly, treatment group 1 was treated with the 7E instructional model integrated with computer animation (X_1), treatment group 2 was treated with the 7E instructional model (X_2), and the control group was treated with conventional methods. The research design is as summarized in Table 1.

Table 1
Research design

Groups	*Pre test*	*Treatment*	*Post test*
Treatment Group1 (TG1)	O_1	X_1	O_2
Treatment Group2 (TG2)	O_3	X_2	O_4
Control Group (CG)	O_5		O_6

Note. X: treatment; O: Outcomes

2.3. Participants

The target population for the study was grade 10 students and biology teachers within Metekel Zone, Ethiopia. The study was focused on students in the tenth grade. This is due to the fact that the study's focus, *food making and growth in plants*, is covered in the grade 10 biology curriculum. The topic was selected for instructions because it is conceptually hard to understand and is suitable for computer animation.

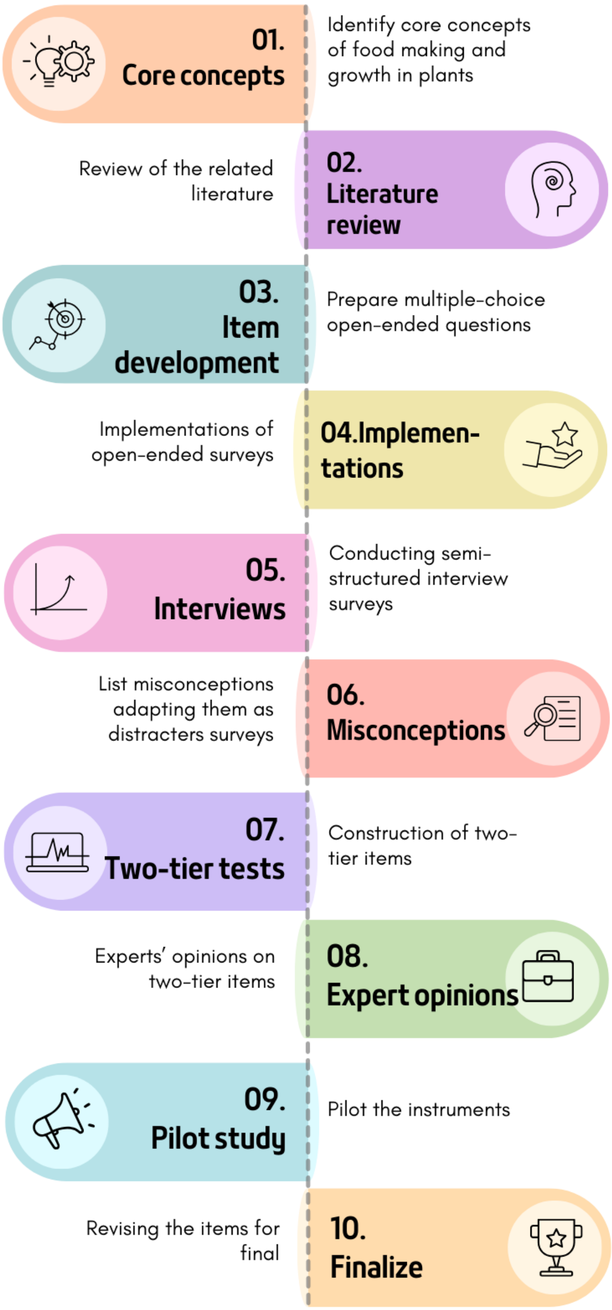
The subjects of the study were three intact classes of grade 10 secondary school students and three regular biology teachers in the Metekel zone secondary schools in Ethiopia. Three schools were selected using purposive sampling for the intervention. The three schools that had comparable conditions in terms of school facilities, teachers' qualifications, experience, and school effectiveness were purposefully selected for the intervention. This was done to ensure that the sampling effect would be minimized. The selected sections were randomly assigned as a control group, a 7E LCM treatment group, and a 7E LCM with CA treatment group. Three biology teachers were randomly selected and assigned to the three classes. From each of the selected schools, one biology teacher was selected randomly from among the biology teachers since each school had more than one biology teacher. One biology teacher and one section grade 10 students were randomly chosen from each of the three schools. The study involved 151 tenth grade students (77 boys and 74 girls) in the selected government secondary schools. There were 51, 48, and 52 students in 7E with CA, 7E, and conventional groups, respectively. The study's students were chosen based on the fact that they had not yet been taught the topic (content) that was used in this study, ensuring class equality before being used as research classes. Treatment groups and comparison groups were not equal in size because the schools were taken as intact groups, which had a different number of students. Moreover, in order to triangulate the conceptual understanding data, 18 students were selected using purposive sampling for semi-structured interviews after the intervention.

2.4. Instruments

A two-tier conceptual understanding multiple-choice test was used in the study. Two-tier tests are considered a practical and valuable way of assessment since they justify students' answers, decrease hypothetical answers, offer large-scale use, enable the process to be managed easily, enable easy scoring, and present ideas on the way of students' thinking(Othman et al., 2008). The first tier consists of a content question about food making and growth in plants with two, three, four, or more choices, while the second tier consists of three, four, or more possible reasons for the first part: three, four, or more alternative reasons, plus one desired reason. The design of the diagnostic instrument was based on the procedures described by (Haslam & Treagust, 1987; Lin, 2004; Roth et al., 1983; Treagust, 1988; Vitharana, 2015). The design of the diagnostic instrument was based on ten major steps (see Figure 1). This process was conducted to find common conceptual understandings and misconceptions in food making and plant growth.

In addition, semi-structured interviews were also conducted to assess students' understanding of food production and growth in plants concepts and misconceptions.

Figure 1
Development process of two-tier conceptual understanding test



2.5. Pilot Study

A pilot test was done at a school not included in the sample to assess the practicability of the models and computer animations, the difficulty and discrimination level of test items, and the reliability of instruments. A pilot biology conceptual understanding test was administered to 97 grade 11 students to ensure reliability.

2.5.1. Item analysis

The food making and growth in plants conceptual understanding test had an average difficulty level of 0.4, indicating moderate difficulty for students (see Table 2).Most items were in an acceptable difficulty range, with some revised. Two items were dropped.

The food making and growth in plants conceptual understanding test had a mean discrimination index of 0.3, indicating discriminating well between high and low achiever students

(Table 2). Two items, items 12 and 18, were reviewed and dropped. The final version of a 22-item conceptual understanding test was administered to all treatment and comparison groups.

Table 2

Item difficulty (P) and discrimination index (D) for food making and growth in plants conceptual understanding test

Test item type	*Difficulty indices (p)*	*No. of items*	*Discrimination indices (D)*	*No. of items*
Conceptual understanding test	$(0.4 \leq p < 0.6)$	16	$D \geq 0.4$	1
	$(0.3 \leq p < 0.4)$	6	$0.3 \leq D \geq 0.39)$	9
	$(0.2 \leq p \leq 0.29)$	2	$(0.2 \leq D \leq 0.29)$	12
	$(p < 0.2)$	0	$(D < 0.2)$	2
	Mean = 0.4	Total = 24	Mean = 0.3	Total = 24

2.5.2. Validity and reliability of the instruments

The face and content validity of conceptual understanding tests and semi-structured interviews were confirmed by biology, curriculum, and psychology instructors. In order to make sure that the test is valid, a table of specifications was used to create the test questions. The questions were then assessed by experts to ensure consistency, clarity, and accuracy of the answer key. This was done by comparing the questions to benchmark points, such as the adequacy of sample questions, as well as whether the instructional objectives aligned with the syllabus. Before the pilot study, some of the questions were revised based on feedback and comments from experts. Furthermore, biology professors, experienced teachers, and classroom instructors evaluated the appropriateness of computer animations, and their feedback was incorporated.

The Kuder-Rechardson alpha was used to determine the reliability of the biology conceptual understanding test. The reliability coefficients of the biology conceptual understanding test were found to be 0.77. The values of the biology conceptual understanding test are within acceptable ranges. Therefore, the test items were considered reliable and valid instruments to be used in the current study.

2.6. Intervention Procedure

The research intervention would consist of seven major procedures (see Figure 2). First, the researcher visited participating schools and assigned three sections as treatment and comparison groups. Second, training was conducted for teachers and students in the treatment groups. The training focused on a brief description of the 7E LCM, its developments, and each phase within the model. The training would also cover how teachers can use the model to create a daily lesson plan, with practical examples. Third, the other part of the training would involve technology-based instruction (the use of computer animation) for 7E LCM integrated with the computer animation treatment group. For each lesson, detailed lesson plans for 7E learning cycle model instruction, together with appropriate activities and computer animations, were prepared by the researcher according to the 7E learning cycle model proposed by Eisenkraft (2003), and before each lesson, they were shared with and explained to the classroom teacher (see Figure 3). Fourth, a conceptual understanding pretest was administered to three sections taught by three teachers. Fifth, instructional programs were implemented for eight weeks, where the topic "food making and plant growth" was taught. Treatment groups were taught using 7E LCM and 7E LCM with CA, while the control group was taught using CIM by their regular teachers. All the phases of the 7E instructional model were kept in mind when the activities were going on in treatment groups. Moreover, computer animations were also used for the 7E LCM integrated with the computer animation treatment group. Computer animations were used for the 7E LCM integrated with the computer animation treatment group, covering various aspects of the learning cycle, such as leaf parts, transport in plants, stomata, photosynthesis stages, seed germination, and tropic responses. The researchers did not interfere with teaching in the comparison groups. Sixth, a post-test was administered one week after the completion of the instructional program. A semi-structured interview and a conceptual understanding test were administered by the researcher and regular teachers, respectively, as post-tests. Finally, the researcher would collect pre-test scores and post-test scores.

Figure 2
Flow chart of the intervention procedure

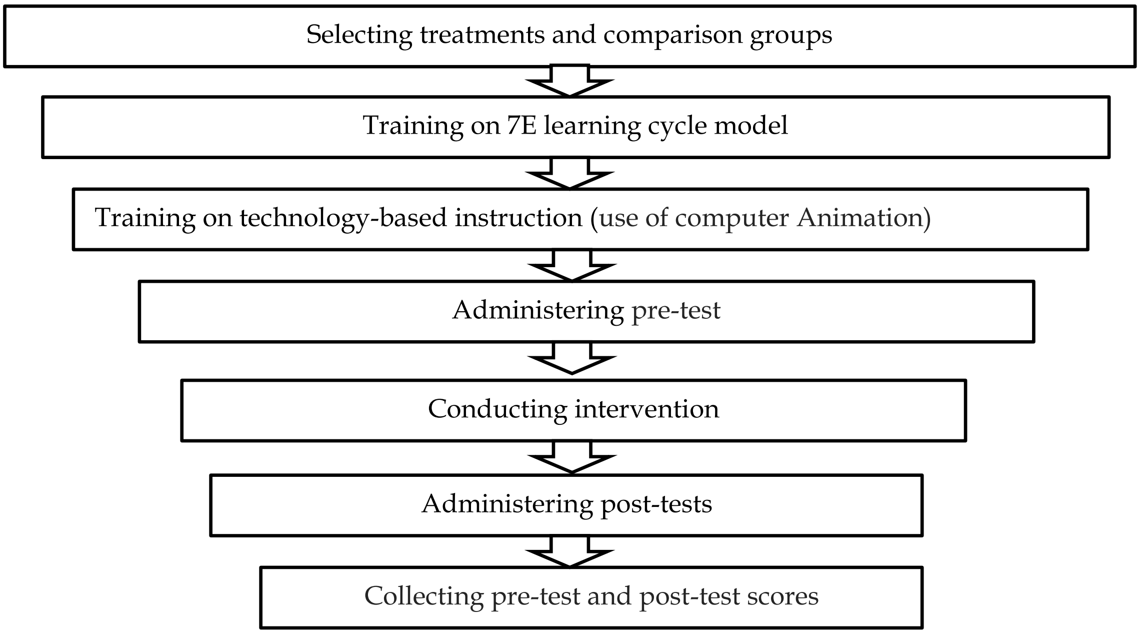
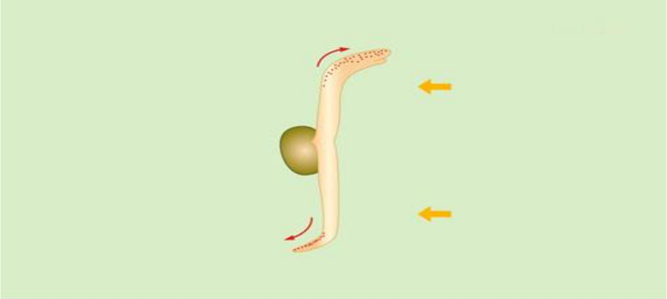


Figure 3
Animation regarding the different effect of auxin on the growth of roots and shoots



2.7. Data Analysis

Statistical Package for Social Sciences version 26 software was used to analyze the data. The data was analyzed using both descriptive and inferential statistics. Descriptive statistics were used to summarize, compare, and explain results from treatments and control groups in terms of the mean score, range, maximum and minimum values, standard deviation, skewness, kurtosis, frequency tables, and bar graphs for the data obtained from students in treatment and control groups. The ANOVA and MANOVA statistical tools were used to analyze test scores. The ANOVA statistical tool was used to analyze pre-test scores, based on basic assumptions of independent measurement, normal distribution of dependent variables, and equal variance across groups (Pallant, 2020). ANOVA was used to check the equality of groups in their scores on the conceptual understanding test and misconceptions before the treatment. An ANOVA also was used to determine the mean score difference of three different instructional methods on students' conceptual understanding and misconceptions related to food production and growth in plants concepts.

In addition, MANOVA was used to examine the gender effect on students' conceptual understanding and misconceptions. In addition to descriptive and inferential statistics, the percentage of students’ responses to conceptual understanding and misconceptions was calculated. Similarly, data obtained from conceptual understanding test was also be categorized, analyzed, and compared among the four groups in relation to sound understanding, partial understanding, no understanding, and misconceptions. According to Ozkan and Selcuk (2015), if students scored both tiers correct considered as sound understanding, if first tier correct and second tier incorrect as misconception, if first tier incorrect and second tier correct as Partial understanding and if both tiers incorrect as No understanding. Misconceptions are considered significant and common if they are held at least 10% of the total sample of students (Chandrasegaran et al., 2007). Qualitative data was transcribed and categorized into topics for analysis. Students' responses to interview questions were compared among the three groups.

2.8. Ethical Issues of the Study

The study aimed to reduce treatment gaps in Metekel zone secondary schools by using 7E LCM and CA. Permission was obtained from the University of Bahirdar, and formal requests were made to participating schools. Participants were informed of the research's purpose, voluntary participation, confidentiality, and not expected to provide identifiable information in tests.

3. Results

3.1. Results of Pretest Scores Analysis

Before the process of analysis of pre-test scores, the assumptions of the ANOVA were checked. As the first assumption of ANOVA, univariate normality was checked. The skewness and kurtosis of the variables were used to check normality. From the outputs provided in Table 3, it can be seen that all of these variables have skewness and kurtosis values between −1 and 1, which were in an acceptable range in both cases. As the second assumption of the ANOVA, the independent observation was met. Each set of participants was assessed under the same treatment condition, and independent measurement was ensured in the research design by taking intact classes from the respective schools. Additionally, the same questionnaire was administered to each group simultaneously. Therefore, it is possible to say that students did not affect each other during the test administration process. As a third assumption, the equality of the variances must be checked. The results showed that the assumption of homogeneity of variance (Levene test) was checked and found to be not significant for all dependent variables (Table 3). This means that the variance of scores on each variable for the population of the groups is equal. So, the assumptions for ANOVA were not violated. Thus, the ANOVA was used to compare the means of the three groups on these variables, ensuring the assumptions were met (see Table 3).

Table 3
Skewness, kurtosis and Levene test of homogeneity of variances

Variables	*N*	*Skewness*	*Kurtosis*	*Levene Test of Homogeneity of Variances*	
				F	*p*
Pre- FMGPCU	151	0.781	−0.137	2.526	.083
Pre-MC	151	0.078	−0.261	0.055	.947

3.1.1. Descriptive statistics of pre-test scores

After checking the assumptions for the ANOVA, descriptive statistics of the pre-test scores were analyzed. The descriptive statistics results, as presented in Table 4, revealed that the mean scores of the pre-FMGPCU score of CG students (12.41) was higher than that of TG1 students (11.67), but the scores of TG2 students were almost similar to those of TG1 students (11.55 and 11.67, respectively). However, the mean score of pre-MC in CG students was lower than in TG1 and TG2 (34.70, 35.91, and 36.36, respectively). The descriptive statistics of the pre-FMGPCU and Pre-MC test scores of the groups were summarized in Table 4.

Table 4
The descriptive statistics of Pre- FMGPCU and Pre-MC test scores of the groups

Groups	*N*	*Mean*	*SD*
TG1			
Pre-FMGPCU	51	11.67	5.32
Pre-MC	51	35.91	10.53
TG2			
Pre-FMGPCU	48	11.55	5.92
Pre-MC	48	36.36	10.85
CG			
Pre-FMGPCU	52	12.41	7.03
Pre-MC	52	34.72	9.69

In addition to groups, descriptive statistics of pre-test scores across genders were also computed. As it can be seen from the Table 5, the mean pre-FMGPCU score of male students (13.46) was higher than that of female students (11.36) in CG, and in the same way, the score of male students (12.36) was higher than that of female students in TG 2 (10.67), but the scores of male students were almost similar to those of female students in TG1 (11.88 and 11.45, respectively). Similarly, the mean Pre-MC score of male students (35.48) was slightly lower than female students (36.36) in TG1, and in the same way, the score of male students (34.36) was lower than female students in TG 2 (38.53), and the score of male students (32.51) was lower than female students in CG (32.51 and 36.88, respectively). Table 5 shows descriptive statistics pre-scores across gender.

Table 5
Descriptive statistics for pre- FMGPCU and Pre-MC test Scores across gender

Group	*Variables*	*N*	*Mean*	*SD*
7E LCM with CA	Pre-FMGPCU			
	Male	26	11.88	5.15
	Female	25	11.45	5.58
	Pre-MC			
	Male	26	35.48	12.19
	Female	25	36.36	8.70
7E LCM	Pre-FMGPCU			
	Male	25	12.36	6.88
	Female	23	10.67	4.66
	Pre-MC			
	Male	25	34.36	11.44
	Female	23	38.53	9.96
CIM	Pre-FMGPCU			
	Male	26	13.46	7.32
	Female	26	11.36	6.71
	Pre-MC			
	Male	26	32.51	9.06
	Female	26	36.88	9.98

3.1.2. Inferential statistics of pre-test scores

After performing descriptive statistics, an ANOVA was conducted to check whether there was a statistically significant difference between groups on their pre-FMGPCU and Pre-MC tests. The results from the ANOVA analysis (Table 6) revealed that there was no statistically significant mean difference between the groups in pre-FMGPCU ($F(2, 148) = 0.291$, $p = .748$) and Pre-MC ($F(2, 148) = 0.348$, $p = .706$). This means that the groups were assumed to be the same in their conceptual understanding and misconceptions before the implementation of the intervention. Therefore, the change observed after intervention could not be attributed to treatment group differences before the implementation of the intervention. The ANOVA result is shown in Table 6.

Table 6

ANOVA result comparing groups in terms of pre- FMGPCU and pre- MC tests

Variables		*Sum of Squares*	*df*	*Mean Squares*	*F*	*p*
Pre- FMGPCU	Between Groups	21.996	2	10.998	0.291	.748
	Within Groups	5592.092	148	37.784		
	Total	5614.088	150			
Pre-MC	Between Groups	74.751	2	37.375	0.348	.706
	Within Groups	15879.494	148	107.294		
	Total	15954.244	150			

In addition to groups, inferential statistics of pre-test scores across genders were also computed. The results from the ANOVA analysis revealed that there was no statistically significant mean difference between the genders in pre-FMGPCU ($F(1, 149) = 1.973$, $p = .162$ and pre-MC ($F(1, 149) = 3.473$, $p = .064$. This means that the males and females were assumed to be the same in their conceptual understanding and misconceptions before the implementation of the intervention. So, the change observed after the intervention could not be attributed to gender differences before the implementation of the intervention. The ANOVA result is shown in Table 7.

Table 7

ANOVA result comparing genders in terms of pre- FMGPCU and Pre-MC

Variables		*Sum of Squares*	*df*	*Mean Squares*	*F*	*p*
Pre- FMGPCU	Between Groups	73.373	1	73.373	1.973	0.162
	Within Groups	5540.715	149	37.186		
	Total	5614.088	150			
Pre-MC	Between Groups	363.375	1	363.375	3.473	0.064
	Within Groups	15590.870	149	104.637		
	Total	15954.244	150			

3.2. Results of Posttest Scores Analysis

Before the statistical analysis of these data was made, assumptions for statistical analysis techniques were checked. As the first assumption of ANOVA, the normal distribution of the data can be checked by looking at skewness and kurtosis value. In this study, as presented in Table 8, the skewness and kurtosis values were between −1 and +1. Therefore, the data were approximately normally distributed and hence normality assumption was not violated to run parametric test.

Table 8

Skewness and kurtosis

Dependent variables	*N*	*Skewness*	*Kurtosis*
Post - FMGPCU	151	0.228	−0.513
Post-MC	151	−0.044	−0.005

As the second assumption of ANOVA, the independent observation was met. For this assumption, it is assumed that during the administration of the tests, standardized conditions were provided. As a third assumption, Levene's Test was also investigated to examine the homogeneity of variances between groups. As Table 9 shows, there was no violation of homogeneity of variance assumption for all variables $p > .05$. Table 9 shows the Levene test for the variables.

Table 9

Levene's Test of Equality of Error Variances of post test

Dependent variables	*Levene's Test of Equality of Error Variances* ^{a}			
	F	*df1*	*df2*	*p*
Post- FMGPCU	0.798	5	145	.553
Post- MC	0.697	5	145	.627

Additionally, the assumption of homogeneity of Variance-Covariance Matrices of MANOVA was checked with the Box's Test of Equality of Covariance Matrices. As seen in the Table 10, there was no violation of homogeneity of variance-covariance matrices assumption with Box's M significance values of FMGPCU and Post- MC, $p > .001$ (Pallant, 2020).

Table 10

Box's Test of Equality of Covariance Matrices of Posttest

Variables	*Box's Test of Equality of Covariance Matrices* ^{a}				
	Box's M	F	df1	df2	Sig.
Post test	11.118	0.715	15	112352.3	.772

The study checked for outliers and found no serious violations. The *p*-values for the Mahalanobis distance for post-FMGPCU and post-MC were greater than .001, indicating no outliers. The Mahalanobis distance for post-test data was 8.073, below the critical value of 13.82, indicating no outliers (Pallant, 2020).

Table 11

Mahalanobis distances for posttest scores

Variables	*N*	*Min*	*Max*	*Mean*	*SD*
Post-tests Mahal. Distance	151	0.039	8.073	1.987	1.782

3.2.1. Descriptive statistics of post-test scores

The following section presents the descriptive statistics of post-MC and post-FMGPCU test scores in relation to groups and gender. As it can be seen from the table below (Table 12), the mean scores of the TG 1, TG 2, and CIM on the post-FMGPCU and post-MC tests were different. The mean score for TG 1 (41.087) is higher than TG 2 (34.18) and CG (27.88) in post-FMGPCU, respectively. On the contrary, the mean score for TG1 (25.04) is lower than TG2 (27.36) and CG (30.15) in post-MC, respectively.

Table 12

Descriptive statistics for Post- FMGPCU and Post-MC test Scores across groups

Groups	*N*	*Mean*	*SD*
7E LCM with CA			
Post-FMGPCU	51	41.09	9.45
Post-MC	51	25.04	8.45
7E LCM			
Post-FMGPCU	48	34.18	10.01
Post-MC	48	27.36	9.85
CIM			
Post-FMGPCU	52	27.88	8.54
Post-MC	52	30.15	8.95

In addition to groups, descriptive statistics of post-test scores across genders were also computed. As it can be seen from Table 13, the mean post-FMGPCU score of male students (42.13) was higher than that of female students (40.00) in TG 1. In the same way, the mean post-FMGPCU score of male students (29.37) was higher than that of female students (26.39) in CG, but the score of female students (35.77) was higher than that of male students (32.72) in TG 2. However, the mean post-MC score of male students (23.95) was lower than that of female students (26.18) in TG 1, and that of male students (26.00) was lower than that of female students (28.85) in TG 2. In addition, the score of male students (29.37) was lower than that of female students (30.94) in CG.

Table 13
Descriptive statistics for post- FMGPCU and post-MC test Scores across gender

Group	*Variables*	*N*	*Mean*	*SD*
7E LCM with CA	Post-FMGPCU			
	Male	26	42.13	10.32
	Female	25	40.00	8.50
	Post-MC			
	Male	26	23.95	9.23
	Female	25	26.18	7.56
7E LCM	Post-FMGPCU			
	Male	25	32.72	10.16
	Female	23	35.77	9.81
	Post-MC			
	Male	25	26.00	9.86
	Female	23	28.85	9.84
CIM	Post-FMGPCU			
	Male	26	29.37	8.74
	Female	26	26.39	8.23
	Post-MC			
	Male	26	29.37	9.89
	Female	26	30.94	8.03

3.2.2. Inferential statistics of post- tests scores

As described above, the result of the descriptive statistics revealed that there was a mean score difference between groups and male and female students in relation to post test scores of FMGPCU and post-MC tests. To assess if there were statistically significant post-tests mean score differences between the three groups and gender and if there was an interaction between treatment and gender, MANOVA was conducted. The MANOVA results revealed that there was a statistically significant difference between the three groups on posttest mean scores: F(4, 288) = 11.826^b, *p* = .00; Wilks' Lambda =.738; η^2 = 0.141 (see Table 14). The eta squared (η^2) value is medium or typical value based on the (Cohen, 1988). This eta squared (η^2) value indicated that 14.1 % of multivariate variance of posttest mean scores was associated with the treatment. This means that the difference between the groups accounted for by the treatment.

However, the MANOVA result revealed that there was no statistically significant mean difference between male and female students on posttest mean scores: *F*(2, 144) = 1.130^b, *p* =.326; Wilks' Lambda = .985; η^2 = 0.015. Moreover, the MANOVA result revealed that there was no a statistically significant interaction effect between treatment and gender: *F*(4, 288) = 1.130b, *p* =.326; Wilk's λ = .985; η^2 = 0.015. The following table is the MANOVA result.

Table 14
MANOVA Result – multivariate test

	Wilks' Lambda	*F*	*df*	*Error df*	*p*	η^2
Treatment groups	0.738	11.826^b	4.000	288.000	0.000	0.141
Gender	0.985	1.130^b	2.000	144.000	0.326	0.015
Gender * Treatment groups	0.971	1.079^b	4.000	288.000	0.367	0.015

Tests of between-subjects effects result (see Table 15) confirmed that there was a significant mean difference between groups in post- FMGPCU (p = 0.000), eta squared 0.262 and post-MC

($p = .020$), eta squared 0.053. The eta squared (η^2) values are 0. 262 and 0.053 respectively for post-FMGPCU and Post-MC indicating that 26.7 % and 5.3 % of multivariate variance of dependent variables was associated with treatment. The eta squared (η^2) values are much larger than typical value for post- FMGPCU and medium or typical for post-MC based on the (Cohen, 1988). This implies that the difference between groups in dependent variable was attributed to the intervention.

However, no significant difference was found between males and females in post- FMGPCU (p =.652), eta squared 0.001 and Post-MC (p =.137), eta squared 0.015. Furthermore, the results showed that there was no significant interaction effect between gender and treatment in post-FMGPCU (p =.226), eta squared 0.020 and Post-MC (p =.94), eta squared 0.001.

Table 15

Tests of between-subjects effects

Independent variables	*Dependent variables*	*Type III SS*	*df*	*Mean Square*	*F*	*p*	η^2
Treatment group	Post- FMGPCU	4473.889	2	2236.944	25.726	.000	0.262
	Post-MC	668.624	2	334.312	4.028	.020	0.053
Gender	Post- FMGPCU	17.790	1	17.790	0.205	.652	0.001
	Post-MC	185.581	1	185.581	2.236	.137	0.015
Gender * Treatment group	Post- FMGPCU	260.915	2	130.457	1.500	.226	0.020
	Post-MC	10.235	2	5.118	0.062	.940	0.001

Although the Tests of Between-Subjects Effects result showed that there was a statistically significant mean score difference between treatment groups in all dependent variables, it did not show which group differs from the other one. Therefore, in order to see which group is different from the others, post-hoc multiple comparisons were conducted. In this case, according to Tabachnick et al. (2013) Bonferroni type adjustment should be made in order to ensure a lower Type 1 error on multiple comparisons. Accordingly, to make the adjustment, it is to divide already set alpha by the number of dependent variables of the study. In this study alpha was set to be .05. As a result, when we divided .05 by 2 (dependent variables), it gives .025 which is an adjusted alpha for the multiple comparisons. The two dependent variables for this analysis are conceptual understanding and misconceptions.

The post-hoc multiple comparison result revealed that there that there was statistically significant mean difference between each pair of the groups (p <.025) in FMGPCU mean scores. Students in TG 1 performed better than TG2 and CG with mean gain of 6.90 and 13.20, respectively. However, the post-hoc multiple comparison result revealed that there was no statistically significant mean difference between each pair of the group (p >.025) except between TG 1 and CG (p =.014) in Post-MC mean scores. Students in TG 1 performed better than TG 2 and CG with mean loss of −2.32 and −5.11 respectively in Post-MC. The 7E LCM with CA helped students to score significantly higher mean scores in post-FMGPCU and lower Post-MC indicating its effectiveness over the other methods in enhancing conceptual understanding and minimizing misconceptions followed by 7E LCM.

Table 16

Post-hoc multiple comparison test result

Dependent variable	*(I) Group*	*(J) group*	*Mean Difference (I-J)*	*SE*	*p*
Post-FMGPCU		TG2	6.90	1.87	0.001
	TG1	CG	13.20	1.83	0.000
	TG2	CG	6.30	1.86	0.003
Post-MC		TG2	−2.32	1.83	0.416
	TG1	CG	−5.11	1.79	0.014
	TG2	CG	−2.78	1.82	0.281

In summary, 7E LCM with CA significantly better than the others instructional approaches in improving students' conceptual understanding of concepts in biology and minimize misconceptions followed by 7E LCM.

3.3. Analysis of FMGPCU Items and Misconceptions

In addition to the significant result of the ANOVA, percentages of students' responses to post-FMGPCU and the percentage of students' misconceptions for each item were calculated and analyzed. First, the percentages of students' responses were categorized into sound understanding (SU), partial understanding (PU), misconception (MC), and no understanding (NU). In view of that, the mean percentage of students' responses showed that 41.1, 34.2, and 27.9 of the students for TG 1, TG 2, and CG, respectively, have a sound understanding of the concepts of food making and plant growth (Table 16). On the other hand, 11.9, 12.5, and 15.3 mean percentages of students' responses showed that they have partially understood the concepts, whereas 25.0%, 27.4%, and 30.2% for TG 1, TG 2, and CG have misconceptions about concepts in food making and growth in plants, respectively. Moreover, 21.9, 25.9, and 26.7 mean percentages of students' responses showed that they have no understanding of the concepts for TG 1, TG 2, and CG, respectively. Comparatively, the highest mean percentage of misconceptions was found in CG and TG2 (27.4% and 30.2%, respectively). The misconceptions held by students were relatively lower in TG 1 (25.0), ensuring the effectiveness of the 7E instructional model with CA, than in the others in minimizing misconceptions, followed by TG 2 (27.4) with the 7E instructional model alone. In relation to no understanding of concepts, TG 1 has a lower percentage of students, followed by TG 2.

Furthermore, when each item was analyzed, students in TG 1 performed better in understanding the concept than students in TG 2 and CG in 17 of the items (77.27%) and in 19 of the items (86.36%), respectively. Similarly, students in TG 2 performed better in understanding the concept than students in CG on about 18 of the items (81.81%). In relation to misconceptions, students in TG 1 hold a lower percentage of misconceptions in 14 of the items (68.18%) than in TG2 and in 17 of the items (77.27%) than in CG. Similarly, students in TG 2 hold a lower percentage of misconceptions about 16 of the items (72.72%) than in CG. The percentage of students' responses in TG 1 was higher than the others followed by students in TG 2 in relation to sound understanding and lower in relation to misconceptions and no understanding, indicating that the 7E instructional model with CA was superior to the other instructional methods followed by the 7E instructional model alone in helping students understand the concept. This can be taken as evidence that supports the ANOVA result. Table 17 summarizes the percentage of students' responses for each item in each category.

Table 17
Percentages of students' responses on Post-FMGPCU test scores by category

	Treatment Group 1				*Treatment Group 2*				*Conventional group*			
Item No	SU	PU	MC	NU	SU	PU	MC	NU	SU	PU	MC	NU
1	**56.9**	7.8	27.5	7.8	47.9	8.3	29.2	14.6	28.8	1.9	34.6	34.6
2	43.1	23.5	17.6	15.7	35.4	16.7	22.9	25.0	23.1	34.6	26.9	15.4
3	45.1	13.7	**35.3**	5.9	35.4	4.2	**43.8**	16.7	28.8	9.6	**51.9**	9.6
4	**56.9**	5.9	17.6	19.6	39.6	10.4	14.6	35.4	26.9	21.2	21.2	30.8
5	51.0	11.8	25.5	11.8	37.5	4.2	22.9	35.4	30.8	3.8	32.7	32.7
6	**17.6**	5.9	23.5	52.9	18.8	47.9	12.5	20.8	7.7	42.3	**15.4**	34.6
7	**56.9**	9.8	25.5	7.8	45.8	25.0	25.0	4.2	38.5	17.3	30.8	13.5
8	**17.6**	31.4	33.3	17.6	25.0	8.3	29.2	37.5	32.7	23.1	21.2	23.1
9	29.4	7.8	27.5	35.3	**14.6**	18.8	37.5	29.2	**3.8**	7.7	44.2	44.2
10	47.1	7.8	9.8	35.3	41.7	16.7	8.3	33.3	28.8	9.6	**15.4**	46.2
11	47.1	11.8	29.4	11.8	33.3	2.1	37.5	27.1	28.8	26.9	38.5	5.8
12	27.5	25.5	21.6	25.5	29.2	12.5	25.0	33.3	21.2	1.9	30.8	46.2
13	45.1	2.0	25.5	27.5	39.6	12.5	29.2	18.8	42.3	1.9	21.2	34.6
14	39.2	7.8	17.6	35.3	18.8	20.8	18.8	41.7	7.7	17.3	34.6	40.4

Table 17 continued

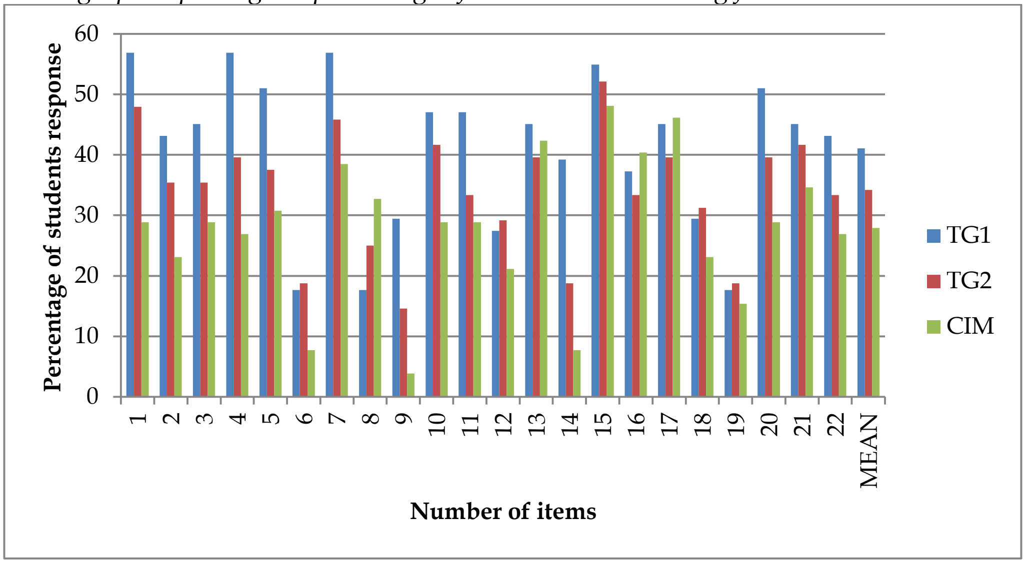
	Treatment Group 1				*Treatment Group 2*				*Conventional group*			
Item No	SU	PU	MC	NU	SU	PU	MC	NU	SU	PU	MC	NU
15	54.9	9.8	21.6	13.7	**52.1**	8.3	29.2	10.4	**48.1**	23.1	26.9	1.9
16	37.3	3.9	31.4	27.5	33.3	2.1	29.2	35.4	40.4	9.6	28.8	21.2
17	45.1	2.0	27.5	25.5	39.6	12.5	37.5	10.4	46.2	1.9	28.8	23.1
18	29.4	2.0	**35.3**	33.3	31.3	2.1	39.6	27.1	23.1	17.3	44.2	15.4
19	**17.6**	15.7	27.5	39.2	18.8	16.7	27.1	37.5	15.4	11.5	21.2	51.9
20	51.0	11.8	21.6	15.7	39.6	2.1	29.2	29.2	28.8	3.8	32.7	34.6
21	45.1	21.6	25.5	7.8	41.7	8.3	27.1	22.9	34.6	17.3	32.7	15.4
22	43.1	23.5	23.5	9.8	33.3	14.6	27.1	25.0	26.9	32.7	28.8	11.5
Mean	**41.1**	**11.9**	**25.0**	**21.9**	**34.2**	**12.5**	**27.4**	**25.9**	**27.9**	**15.3**	**30.2**	**26.7**

Note. SU: Sound understanding; PU: Partial understanding; MC: Misconception; NU: No understanding.

When each item was examined in relation to sound understanding, the highest percentage of sound understanding was recorded for items 1, 4, and 7 for TG 1 (56.9%), item 15 for TG 2 (52.1%), and item 15 for CG (48.1%). In other words, items 1, 4, 7, and 15 were relatively easy for the respective groups. On the other hand, the lowest percentages of sound understanding were recorded for items 6, 8, and 19 for TG 1 (17.6%), item 9 for TG 2 (14.6%), and item 9 for CG (3.8%). In other words, these items were relatively difficult for the respective groups. As it can be seen from Figure 4, students in TG 1 performed better in most of the items, followed by students from TG 2.

Figure 4

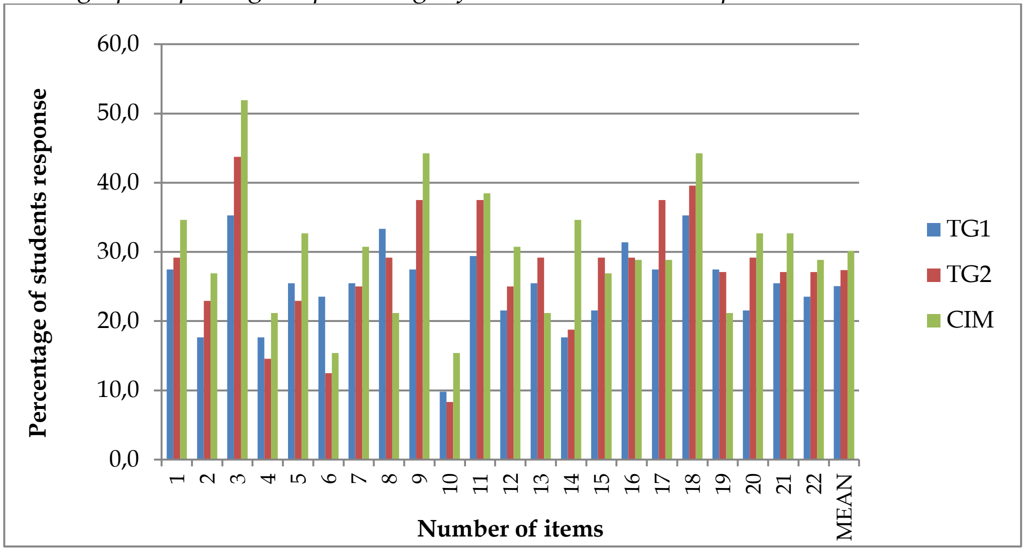
A bar graph depicting the percentage of sound understanding for each item



In relation to misconceptions, the highest percentage of misconceptions was recorded for items 3 and 18 for TG1 (35.3%), item 3 for TG 2 (43.8%), and item 3 for CG (51.9%), respectively. In other words, this item was relatively difficult for three groups. On the other hand, the lowest percentages of misconceptions were recorded for items 10 for TG 1 (9.8%), item 10 for TG 2 (8.3%), and items 6 and 10 for CG (15.4%), respectively. In other words, these items were relatively easy for the respective groups. As can be seen from the Figure 5, students in TG 1 performed better on most of the items in minimizing misconceptions.

Figure 5

A bar graph depicting the percentage of each item's misconceptions



The study analyzed misconceptions about food making and growth in plants, focusing on leaf, photosynthesis, transport system, and response in plants. Forty two major misconceptions were identified from all items and groups, with most of them from comparison groups. The analysis focused on two examples: item 2 and 9. A significant percentage of students had misconceptions about item 2, which pertains to the part of the terrestrial plant's leaf with a high number of stomata. Only 43.14%, 35.42%, and 23.077% from TG2, TG1, and CG understood the reason why most photosynthesis takes place in Palisade mesophyll. A higher percentage of students understood the concept in TG 1 (43.14%), followed by TG 2 (35.42%). However, 7E LCM with CA was found to be more effective than 7E LCM, as only 19.6% of students in TG 1 had misconceptions. Two major misconceptions were identified: students believed most photosynthesis takes place in Palisade mesophyll due to a site with a high concentration of H_2O and CO_2 and that chloroplasts are plant organelles with large air spaces. The responses of students for item 2 were analyzed as shown in Table 18.

Similarly, the results from item 9 showed that 29.41%, 14.58%, and 3.84% from TG 1, TG 2, and CG, respectively, understood the concept that gas is taken up by green plants in large amounts when there is no light energy at all, while others had misconceptions. The relatively higher percentage of students in TG 1 (29.41%) understood the concept. Responses with percentages of 23.07 and 19.23 (CG), 22.92 and 12.5% (TG2), and 11.76 (TG1) were taken as major misconceptions. But three major misconceptions were identified from this item in three groups. The first one is that students considered carbon dioxide gas to be used in photosynthesis, which occurs all the time in green plants. The second misconception is that Oxygen gas is used in respiration, which only occurs in green plants when there is no light energy for photosynthesis. The third misconception is that oxygen is used in photosynthesis, which occurs all the time in green plants. 7E LCM with CA was effective in minimizing misconceptions compared to the other groups. The responses of students for item 9 were analyzed as shown in Table 19.

3.4. Results from Students Interviews

The study conducted semi-structured interviews to assess students' conceptual understanding of food making and plant growth. The interviews were conducted under four sub-topics: leaf, photosynthesis, transport, and response in plants. Students were asked general questions about these topics and specific questions to assess their understanding and misconceptions. The results were analyzed to identify their understanding and misconceptions. Two general and specific question examples were presented to illustrate the process.

Table 18

Percentage of students' responses to item number 2

No	*Two tier item*	*TG1*	*TG2*	*CG*
2	Which of the following is the tissue where most photosynthesis takes place?			
	A. Spongy mesophyll	11.76	10.42	11.538
	B. Stomata	17.65	20.83	25
	C. Epidermis	9.804	10.42	13.462
	D. Palisade mesophyll *	60.78	58.33	50
	The reason for my answer is:			
	1. This tissue has a high CO_2 content.	5.882	6.25	3.8462
	2. There is a high concentration of chloroplasts in this tissue.*	43.14	35.42	23.077
	3. There are numerous air pockets in this tissue.	1.96	4.167	11.53
	4. It is a site where there is a large concentration of H_2O and CO_2.	11.76	12.5	13.46
	5. Other reason: ________________________________.	0	0	0

Table 19

Percentage of students' responses to item number 9

No	*Two tier item*	*TG1*	*TG2*	*CG*
9	Which gas is taken up by green plants in large amounts when there is no light energy at all?			
	A. oxygen gas *	56.86	52.08	48.077
	B. carbon dioxide gas	43.14	47.92	51.923
	The reason for my answer is:			
	1. This gas is used in photosynthesis, which occurs all the time in green plants.	11.76	22.92	19.231
	2. This gas is used in photosynthesis, which occurs in green plants when there is no light energy at all.	9.804	12.5	23.077
	3. This gas is used in respiration, which only occurs in green plants when there is no light energy for photosynthesis.	5.882	2.083	1.9231
	4. This gas is used in respiration, which takes place continuously in green plants.*	29.41	14.58	3.8462
	5. Other reason: __________________________________.	0	0	0

Note. NB. Percentages under reasons are those only with correct first choice; * indicates correct combination of response.

The first general question focused on the general concept of external and internal parts of a leaf and the functions of the different tissues of the plant leaf. When we look at the students' responses, most of the interviewees from all groups described that a leaf has internal and external structures. They mentioned that the different tissues of the plant leaf have different functions.

> There are different external structures of a leaf, such as the apex, midrib, lamina, and leaf blade. The internal structures of the leaf include the epidermis, the palisade mesophyll, chloroplasts, the spongy mesophyll, the vascular bundles, the stomata, and guard cells. The upper and lower epidermis is covered by waxy cuticle. The different tissues of the plant leaf have different functions. For instance, the waxy cuticle prevents water loss, the palisade mesophyll allows maximum photosynthesis, and the stomata allow the diffusion of gases into and out of the leaf (Student B, TG 1).
>
> There are different types of leaf structures, such as internal and external structures. For instance, the apex, midrib, lamina, and blade are external structures, while palisade mesophyll, spongy mesophyll, vascular bundles, chloroplasts, and stomata are internal structures. Each structure has its own function. For example, chloroplasts produce chlorophyll to absorb sunlight (Student G, TG 2).
>
> A leaf has internal and external structures. The interviewee has a problem identifying internal structures from the external structure of a leaf. He mentioned the stomata as an external structure of the leaf that is used for gas exchange (Student A, CG).

The first specific question focused on the site where the majority of photosynthesis occurs and the reason behind it. Only some of the interviewees from TG 2 and most of the interviewees from TG 1 answered correctly, but very few students from CG said that the majority of photosynthesis occurs in palisade mesophyll due to the high concentration of chloroplasts. When interviewees were asked to CG, they failed to answer the interview and the reason why the majority of photosynthesis occurred. Below is a sample excerpt from each group:

> The majority of photosynthesis occurred in palisade mesophyll. This is due to the presence of a high concentration of chloroplasts (Student B, TG 1).
>
> I think the majority of photosynthesis occurred in palisade mesophyll due to it is a site where there are numerous air pockets in this tissue (Student G, TG 2).
>
> The majority of photosynthesis occurs on palisade mesophyll because it is a site where there is a large concentration of H_2O and CO_2 and large air spaces (Student A, CG).

In this category, it seems that interviewees from TG 1 and TG 2 explained that the majority of photosynthesis occurs on palisade mesophyll and the reason behind it. The misconception that the majority of photosynthesis occurs on palisade mesophyll due to numerous air pockets and that it is a site where there is a large concentration of H_2O and CO_2 was also identified during the interview.

The second general question focused on the general concept of chemical reactions in photosynthesis. When we look at the students' responses, most of the interviewees from all groups described that there are different types of chemical reactions in photosynthesis, but there are two major types of chemical reactions: light reactions and dark reactions.

The second specific question was related to the type of gas used and released in large amounts during the day and night. Almost all students from TG1 give the response correctly. They mentioned that CO_2 and O_2 are used during the day for purposes of photosynthetic activity and cellular respiration, respectively. They also mentioned that CO_2 is released all the time due to respiration, while O_2 is only released during the day. However, there was difficulty answering this question correctly in TG2 and CG. Students mentioned that oxygen gas is released during the night and plants only respire at night. These were misconceptions that students held. Sample excerpts are presented as follows:

> O_2 and CO_2 are used during the day. Plants use oxygen and CO_2 due to cellular respiration and photosynthesis, respectively. Plants release oxygen and CO_2 due to photolysis of water molecules and cellular respiration during the day, respectively. Unlike to this plants release out CO_2 during the day and night due to cellular respiration (student B, TG1).

> Plants release oxygen and CO_2 all the time due to photolysis of water molecules and respiration, respectively. He also mentioned that plants use CO_2 and O_2 all the time due to photosynthesis and respiration (students G, TG2).
>
> Plants release oxygen all the time due to the photolysis of water molecules. He also mentioned that plants release CO_2 during the day and night due to cellular respiration (students A, CG).

This result also provides supportive evidence for quantitative data showing that TG 1 students were better at understanding concepts and minimize misconceptions followed by 7E LCM.

4. Discussion

The aim of this study was to investigate the effect of the 7E instructional model integrated with computer animations on students' food making and plant growth conceptual understanding and their misconceptions in Metekel Zone secondary schools, North Western Ethiopia. To achieve the goal of the study, a non-equivalent pretest, multiple treatments, and posttest control group quasi-experimental research design was used. The students in the experimental groups were instructed in the 7E learning cycle model integrated with computer animation and the 7E learning cycle model, while those in the control group were instructed on the same concept through a conventional approach for two months. A two-tier multiple-choice test was used to assess their conceptual understanding of plant food production and growth. The results showed no significant difference between the groups in pre-FMGPCU and pre-MC tests, indicating that the change observed after the intervention could not be attributed to treatment group differences. Additionally, no significant difference was found in pre-test scores across genders, indicating that males and females were assumed to be the same in their conceptual understanding and misconceptions before the intervention.

After the intervention had been carried out, a post-test was also given for the three groups after a week. To assess if there were statistically significant post-test mean score differences between the three groups and gender and if there was an interaction between treatment and gender, a MANOVA was conducted. As described in the result of the descriptive statistics, there was a mean score difference between groups in relation to the post-test scores of the FMGPCU and Post-MC tests. The MANOVA results revealed that there was a statistically significant difference between the three groups on posttest mean scores. This means that the difference between the groups was accounted for by the treatment. The results revealed that treatment and comparison group students improved their understandings, minimizing misconceptions from the beginning of the instruction to the end of the instruction.

Tests of between-subject effects confirmed that there was a significant mean difference between groups in post-FMGPCU and post-MC. This implies that the difference between groups in the dependent variable was attributed to the intervention. Although the Tests of Between-Subjects Effects result showed that there was a statistically significant mean score difference between treatment groups in post-FMGPCU and post-MC, it did not show which group differed from the other one. Therefore, in order to see which group is different from the others, post-hoc multiple comparisons were conducted. The post-hoc multiple comparison result revealed that there was a statistically significant mean difference between each pair of the groups ($p <.025$) in FMGPCU mean scores. Students in TG 1 performed better than students in TG2 and CIM, with mean gains of 6.90 and 13.20, respectively. Similarly, the post-hoc multiple comparison result revealed that there was no statistically significant mean difference between each pair of the group ($p >.025$) except between TG 1 and CIM ($p = .014$) in post-MC mean scores. Students in TG 1 performed better than students in TG 2 and CIM, with mean losses of -2.32 and -5.11, respectively, in Post-MC. The 7E LCM integrated with CA helped students score significantly higher mean scores in post-FMGPCU and lower in post-MC, indicating its effectiveness over the other methods in enhancing conceptual understanding and minimizing misconceptions. These findings are supported by the findings of models which showed the use of multimedia-assisted instructional activities that simulate students' visual and thinking patterns will positively affect student achievement in teaching those concepts that are hard for students to comprehend (Bülbül, 2010; Kocakaya & Gonen, 2010; Miadi et al., 2018; Sarac & Tarhan, 2017; Warliani et al., 2017). The difference may be a result of the interactive nature of computer animation, which provides the students with an opportunity to be actively involved in the learning process. The result is that in the literature concluded similar results that the materials developed in accordance with the 7E model are effective in increasing the academic achievement of the students in their studies (e.g. Kunduz & Secken, 2013; Marbach-Ad et al., 2008; Polyiem et al., 2011; Siribunnam & Tayraukham, 2009).

It has been widely reported that 7E LCM, supported by computer animation, improved students' conceptual understanding more than conventional instructional models by different researchers. For example, Bülbül (2010) compares the effectiveness of the instruction based on the 7E learning cycle model accompanied with computer animations and traditionally designed osmosis and diffusion topic instruction on students' conceptual understanding in Istanbul. The results indicated that instruction based on the 7E learning cycle model accompanied by computer animations significantly improved students' conceptual understanding and minimized misconceptions. Similarly, Warliani et al. (2017) and Miadi et al. (2018) studied the effectiveness of the 7E Learning Cycle using TBCT (technology-based constructivist teaching) on students' conceptual understanding of mechanical wave material and static fluid concepts in Indonesia, respectively. Their research used the quantitative method of a quasi-experimental design with a pretest-posttest controlled group. Multiple-choice tests were used in their study to assess the conceptual understanding of students. Their findings showed that the 7E Learning Cycle using TBCT was significantly superior to the 7E Learning Cycle using the CT (constructivist teaching) approach for improving students' conceptual understanding and minimizing misconceptions. However, this study used a two-tier multiple-choice test and a semi-structured interview to deepen the students' responses and get a clear picture of their understanding. Hence, this research was done in Ethiopia, which is quite different in terms of the infrastructure available to schools compared to previous study areas in Istanbul and Indonesia. It is also true that the contents of the study focus on the grade ten topics "food making and growth in plants," which are other than diffusion and osmosis, wave material, and static fluid concepts, to generalize the effectiveness of 7E LCM in different contexts, grade levels, and topics of biology in Ethiopia. Further, the current study was done in the 7E learning cycle model integrated with computer animations, the 7E learning cycle model, and conventional method groups, while previous studies were done in the 7E learning cycle model accompanied with computer animations and conventional method groups in Istanbul, and the 7E learning cycle using TBCT and 7E LCM groups in Indonesia. This helps to generalize the effectiveness of the 7E learning cycle model accompanied by computer animations compared to the conventional method.

Furthermore, the 7E learning cycle model has been identified as one of the most prevalent constructivist teaching approaches that takes into account students' developmental levels and helps them use their prior knowledge as they learn new thought processes, develop higher levels of thinking, and become aware of their own reasoning. The effectiveness of 7E learning cycle approaches on conceptual understanding is supported by a large body of research (Baybars & Kucukozer, 2018; Irsyad et al., 2018; Primanda et al., 2019; Vallespin, 2021; Wodaj & Belay, 2021). For example, Wodaj and Belay (2021) investigate the effect of the 7E instructional model with metacognitive strategies on students' understanding and misconceptions in human biology contents conducted in four government schools in the capital city, Addis Ababa. The research method was a mixed research method with a quasi-experimental design with a pretest, treatment posttest, and delayed posttest. The study had three treatment groups (1, 2, and 3) and one comparison group that was assigned at random. The 7E instructional model was used in treatment group one; the 7E instructional model with metacognitive strategies was used in treatment group two; conventional instruction with metacognitive strategies was used in treatment group three; and conventional instruction alone was used in the comparison group to teach human biology for

10 weeks. Their findings showed that the 7E instructional model supported by metacognitive strategies was significantly superior to conventional instruction for improving students' conceptual understanding of concepts in learning biology and minimizing misconceptions. Their findings are limited to human biology in the ninth grade biology course. However, this research was conducted in the Metekel zone, which is quite different in terms of the infrastructure available to schools compared to the previous study area in Ethiopia. It is also the contents of the study that are focused on the grade ten topics "food making and growth in plants," which are other than human biology concepts, to generalize the effectiveness of 7E at different regions, grade levels, and topics of biology in Ethiopia. In addition, this study considered computer animation as another metacognitive strategy in knowledge cognition compared to a previous study in Ethiopia.

In addition to the significant result of the ANOVA, percentages of students' responses to post-FMGPCU and misconceptions identified provided evidence of the difference between the groups after the treatment, supporting the effectiveness of the intervention. In relation to students' responses to sound understanding, partial understanding, misconception, and no understanding, the mean response of students was calculated. In view of that, when we look at the percentage of students' responses, the mean percentage of students' responses showed that 41.1, 34.2, and 27.9 of the students for TG 1, TG 2, and CIM, respectively, have a sound understanding of the concepts of food making and plant growth. On the other hand, 11.9, 12.5, and 15.3 mean percentages of students' responses showed that they have partially understood the concepts, whereas 25.0%, 27.4%, and 30.2% for TG 1, TG 2, and CIM have misconceptions about concepts in food making and growth in plants, respectively. Moreover, 21.9, 25.9, and 26.7 mean percentages of students' responses showed that they have no understanding of the concepts. Comparatively, the highest mean percentage of misconceptions was found in TG2 and CIM (27.4% and 30.2%, respectively). The misconceptions held by students were relatively lower in TG 1 (25.0), ensuring the effectiveness of the 7E instructional model with CA, than in the others in minimizing misconceptions, followed by TG 2 (27.4) with the 7E instructional model alone. In relation to no understanding of concepts, TG 1 has a lower percentage of students, followed by TG 2. Furthermore, interview results showed that students in TG 1 had better understanding of food making and plant growth concepts and lower misconceptions. This aligns with previous research finding of (Bülbül, 2010; Celik et al., 2013; Gönen et al., 2006; Kencana et al., 2020; Kocakaya & Gonen, 2010; Miadi et al., 2018; Sarac & Tarhan, 2017; Warliani et al., 2017; Wodaj & Belay, 2021).

The finding illustrates that students hold varying misconceptions about all topics of plant life, especially the leaf, photosynthesis, transport in plants, and response in plants. These alternative conceptions were prompted by the difficulty and complexity of the concepts, existing conceptual understandings, language, daily-life experiences, and missing interpretations of representations (Chuenmanee & Thathong, 2017). This confirms that students come to school with plenty of knowledge about the physical world based on their daily experiences.

Students who learned with the 7-E learning cycle model integrated with computer animation had a higher conceptual understanding of biology and fewer misconceptions about food making and growth in plants than those who learned with 7-E learning cycle model and the conventional approach. The reason why the learning conceptual understanding of students who learned from the 7-E learning cycle model integrated with computer animation was higher than that of those who learned from the conventional approach was because the learning model included the phases to check the students' own knowledge so that they would use it for their further study, then they would learn accurately (Eisenkraft, 2003; Siribunnam & Tayraukham, 2009). In line with the development theory of Piaget, knowledge construction in learning cycle instruction can be explained as follows in the light of related literature (Balci et al., 2006; Bülbül, 2010; Eisenkraft, 2003; Siribunnam & Tayraukham, 2009).

The first phase of the cycle activates students existing knowledge and prepares them to construct connected knowledge structures. For example, in the current study, at the elicit stage of the 7E learning cycle model, students' misconceptions about food making and growth in plants were identified. However, students' misconceptions about food making and plant growth were ignored in instruction based on conventional instruction methods. Therefore, students who were instructed by conventional instruction methods could not construct knowledge and understanding for the meaningful learning of food making and plant growth. Because meaningful learning can only be achieved when students have appropriate mental structures and can relate them to new knowledge.

In the engagement stage, activities were used to capture students' attention, get students thinking about the subject matter, raise questions in students' minds, stimulate thinking, and access prior knowledge. For example, to gain the students attention on the topic "internal structure of a leaf," the teacher asks students to immerse a leaf in beaker hot water. Count the number of air bubbles that come out of each side of the leaf. On which side of the leaf do more air bubbles come out? Why? Students do an activity and give their response. This way, students will get to know the internal structure of a leaf and will be naturally motivated to learn.

In the present study, exploration phases mostly covered hand-on and mind-on activities related to the leaf, photosynthesis, transport system, and response in plants. The activities that were involved in the exploration phase focus on generating ways in which the students may perceive scientific phenomena occurring around them. This includes identification of the systematic procedures, recording information, developing hypotheses, designing and planning suitable investigations, isolating variables, interpreting outcomes, constructing graphs, and arranging the conclusions. At this point, the cognitive conflict rose in the student's existing mental structures, and new situations caused disequilibrium, which the individual avoided. To be able to reach equilibrium, they accommodate the concept in an environment where they are allowed to explain and discuss their ideas in the explanation phase based on the data obtained from the exploratory activities. This phase is essential to allow students to accommodate through the discussion and interpretation of data. The teacher let the students share their ideas and helped them acquire the scientific terminology for the topic.

In the elaboration phase, both assimilation and accommodation occur since the students organize or relate the newly developed concept to prior concepts or daily life applications. The evaluation phase also makes students realize the change in their knowledge and assess their own conceptions to make the necessary arrangements. In the elaboration phase, the activities were arranged so that the students got a chance to apply the prior information to the new situation. It includes posing innovative questions and formulating hypotheses to be tested. The activities that were involved in the evaluation phase gave students a chance to evaluate what they had developed. The teachers used different activities, like role-playing, mind maps, etc., to evaluate the learning outcomes. Finally, at the extension phase, the students were supposed to learn the concepts; therefore, the activities in this phase were arranged so that the transference of learning was focused. Moreover, the effectiveness of computer animation may be attributed to several factors, some of which are learners’ ability to visualize the 3D object, receive immediate feedback, self-paced learning, reinforcement, principles of mastery learning, associate learning, and step-by-step learning, among others (Gambari et al., 2014). It also facilitates the learner's encoding process and increases self-esteem and motivation (Gambari et al., 2014; Lin, 2001). All these attributes of a computer animation package make it a unique instructional tool. Furthermore, address issues related to the deficient traditional education system and educational resources currently in use in the 7E LCM integrated with the computer animation treatment group when compared to other groups.

The study used animations to teach students about plant structures, transport, photosynthesis, and response in plants. The first animation focused on leaf parts, while the second explained the uptake of mineral salts and water movement in plants. The third animation explained the movement of organic materials in phloem. The fourth animation focused on stomata, the stages of photosynthesis, seed germination, and tropic responses. Through the illustrated mechanism, the biological processes and structures that were hard for them to understand were shown in a better way. Hence, these computer animations have a positive effect on increasing the attention and curiosity of students, and they facilitate conceptual learning. As the result, students in this study benefited from the combined advantages of both the 7E instructional model and computer animation strategies so as to enhance their conceptual understanding and minimize misconceptions. Similarly, different studies conducted to compare the effectiveness of 7E LCM with CI on students' conceptual understanding of concepts and reported significant results in favor of 7E LCM. Similarly, different studies conducted to compare the effectiveness of 7E LCM with CA with CIM on students' conceptual understanding of concepts reported significant results in favor of 7E LCM with CA (Bülbül, 2010; Celik et al., 2013; Gönen et al., 2006; Kencana et al., 2020; Kocakaya & Gonen, 2010; Miadi et al., 2018; Sarac & Tarhan, 2017; Warliani et al., 2017). Thus, the integration of 7E LCM with computer animations improved knowledge construction and minimized misconceptions compared to 7E LCM and conventional instruction methods.

Another major finding of this study is that there is a gender difference in the conceptual understanding and misconceptions of students taught using 7E LCM with CA, 7E LCM, and CIM. The result indicated that differences existed between the gains in mean scores of the male students and those of the female students in conceptual understanding and minimizing their misconceptions. That is to say, those male students achieved better conceptual understanding and minimized misconceptions in biology when taught with 7E LCM integrated with computer animation than with 7E LCM and CIM. However, the MANOVA result revealed that there was no statistically significant mean difference between male and female students on the FMGPCU and post-MC tests. Furthermore, the MANOVA result revealed that there was no statistically significant interaction effect between treatment and gender. As a result, male and female students benefited similarly from the intervention's implementation. This finding is in line with the previous studies (e.g. Balta & Sarac, 2016; Huppert et al., 2002; Ugwu & Soyibo, 2004; Wodaj & Belay, 2021). This finding, however, is inconsistent with the findings of some other studies (e.g. Adeyegbe, 2004; Alparslan et al., 2003; Cavallo et al., 2004; Chikendu, 2018; Nworgu, 2005; Jimoh, 2004). For example, Alparslan et al. (2003) found gender differences in the relative effectiveness of two modes of treatment for 11th grade students' (conceptual change instruction and traditional instruction) on understanding respiration. Their study indicated a significant difference between girls' and boys' performance in favor of the girls, but they found the interaction of the treatment with gender differences to be non-significant for learning the concepts. According to Nworgu (2005), males have been found to be more prevalent in mathematics and physical sciences, but both sexes are almost equally represented in biological science courses. Adeyegbe (2004) found male students performing generally better than females in physics, chemistry, and biology. Similarly, Chikendu (2018) discovered a gender difference in academic achievement between students taught using instructional computer animation and those taught using traditional methods. The results revealed that there were differences in mean score gains between male and female students. That is, when taught with instructional computer animation, female students outperformed male students in chemistry. Jimoh (2004) also held the same view that differences exist in the academic achievement of boys and girls in chemistry. It does appear that these gender differences in students' achievement vary with the method of instruction.

In summary, the 7E learning cycle model integrated with computer animation treatment is significantly better than the other instructional approaches in improving students' conceptual understanding of concepts in biology and minimizing misconceptions. However, the mean scores reported in conceptual inventories after the intervention two months later revealed that students' in both experimental and comparison groups still hold some misconceptions. Considering the maximum score of 22 (100%) that was possible to get in the conceptual inventories, none of the group members were able to reach the score after the instruction. This finding implied the robustness of students' misconceptions to change. As also argued by the other researchers, the transformation of scientific understanding in the course of instruction is possible to some extent since the existing conceptions are powerful and resist modifying or refining completely (Gök, 2014;

Sungur et al., 2001). Similar results in terms of the misconceptions that remained after the learning cycle were also found in the studies (Aydemir, 2012; Gök, 2014; Kaynar et al., 2009;Wodaj & Belay, 2021). In the current study, however, students in the comparison group reported lower scores, accounting for more misconceptions compared to students in the experimental group. This finding is also compatible with previous research that supports the claim that compulsory education that directs traditional methods of teaching is not promising to eliminate existing misconceptions or provide meaningful learning (Aydemir, 2012; Gök, 2014; Sungur et al., 2001). Furthermore, this research was conducted in different regions, topics, metacognitive strategies, and grade levels to increase the generalizability of the conclusions.

5. Conclusion

Based on results and discussion, it can be concluded that the 7E learning cycle model integrated with computer animation helped students understand biology concepts better than learning with only the 7E LCM alone. When students are supported with computer animation, they greatly benefit from 7 LCM in terms of understanding concepts and minimizing misconceptions. Moreover, students benefited more from 7E LCM alone than from CIM in understanding biology concepts and minimizing misconceptions. The findings of this study indicated that students taught with the 7E learning cycle model integrated with computer animation treatment performed significantly better than students taught with other instructional approaches in improving their conceptual understanding of concepts in biology and minimizing misconceptions. This implies that the difference between groups in the dependent variable was attributed to the intervention. It can be said that in the near future, the 7E learning cycle model integrated with computer animation methods may comprise effective teaching methodologies for developing deep conceptual understanding and minimizing misconceptions in various disciplines. However, no significant difference was found between males and females in conceptual understanding and misconceptions. This indicates that the learning cycle 7E model integrated with computer animation still has a need for further development to explore the implementation effect size and this model in the learning processes of food making and plant growth. Although the number of participants in this study is limited, the study seems to help close the gap between biology students' experiences and their views about developing activities based on the 7E learning cycle model integrated with computer animation. The findings of this study have practical implications for science education and biology education, particularly for teachers, students, and writers of science text books.

6. Recommendation

Based on the results of the research, some suggestions are made. First, computer-animated teaching materials should be prepared according to the 7E learning model, and the processing of the course can be applied to other units of the Biology and Science course. Second, teachers should be offered in-service training activities regarding the 7E learning cycle model integrated with computer animation, and they should follow related advances. Third, curriculum planners should incorporate and lay emphasis on the 7E learning cycle model integrated with computer animation as an alternative to the conventional lecture method. Fourth, science teachers, especially those in the field of biology, should employ the 7E learning cycle model integrated with computer animation that allows students to construct their own knowledge and actively participate in the learning process. Finally, the study suggests that educational policymakers, curriculum planners, teachers, and other stakeholders should consider implementing the 7E learning cycle model integrated with computer animation for more meaningful science education, particularly in biology, in Ethiopia.

Author contributions: All authors contributed all the processes of producing the paper, including conceptualizing, writing, analyzing the data, and reporting the results, and language editing.

Declaration of interest: No potential conflict of interest was reported by authors.

Ethics declaration: Authors declared that the study was approved by Science Faculty of Bahir Dar University on 01.26.2023 with approval code: PRCSVD/590/2015.

Funding: No funding source is reported for this study.

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