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Effects of the Modality and Segmenting Principles on Gear Instruction

by

Tengzhang (Barry) Huang

A dissertation

submitted in partial fulfillment

of the requirements for the degree of

Doctor of Education in the Department of School Psychology

and Educational Leadership

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Committee Approval

To the Graduate Faculty:

The members of the committee appointed to examine the dissertation of TENGZHANG "BARRY" HUANG find it satisfactory and recommend that it be accepted.

Dr. David Coffland,
Major Advisor, Chair

Dr. John Curry,
Committee Member

Dr. Ajit Bhattarai
Committee Member

Dr. Geoffrey Thomas
Committee Member

Dr. Cynthia Blanton
Graduate Faculty Representative

IRB Approval

Idaho State University

April 11, 2023

Barry Huang
Education
MS 8059

RE: Study Number IRB-FY2023-181: Effects of the Modality and Segmenting Principles on Gear Instruction

Dear Mr. Huang:

Thank you for your responses to a previous review of the study listed above. I agree that this study qualifies as exempt from review under the following guideline: Category 1. Research, conducted in established or commonly accepted educational settings, that specifically involves normal educational practices that are not likely to adversely impact students' opportunity to learn required educational content or the assessment of educators who provide instruction. This includes most research on regular and special education instructional strategies, and research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.
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Sincerely,

Ralph Baergen, PhD, MPH, CIP
Human Subjects Chair

Office for Reseach - Research Outreach & Compliance
921 South 8th Ave., Stop 8386 | Pocatello, ID 83209-8286 | (208) 282-1336 | isu.edu/research

Dedication

As a student who had traveled a long distance to come to America, I would like to thank my parents for consistently respecting my choices and supporting my studies.

To my wife, thank you for your unlimited love, support and encouragement. You are my lightning rod, Ting!

Finally, I want to thank myself! You did it! You were doing great! You finally got it done! You may be able to take a small rest now, but this is not where you will stop! So Now Run! Barry! Run……

Acknowledgements

Thanks to all the individuals who have generously provided their assistance, support, and encouragement throughout my educational journey. Countless people have imparted valuable guidance, shared insightful advice, and offered unwavering motivation, and for their contributions, I am sincerely thankful. My heartfelt appreciation goes out to everyone who has played a pivotal role in fostering my personal and academic growth during my pursuit of education.

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I would also like to thank Kyle, who is the son of Dr. Coffland, for his invaluable assistance in dubbing all of my instructional videos. His professional voice served as a crucial component in my study.

I am immensely grateful for the unwavering support and encouragement of my wife, Tingxuan, throughout my journey as an Ed.D student. Her assistance in recruiting participants and analyzing data alongside me has played a crucial role in the success of my studies. I am sincerely thankful for her significant contributions to my research.

Thank all the people who participated in my study during this difficult time, thank you for your time and support.

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Effects of the Modality and Segmenting Principles on Gear Instruction

Dissertation Abstract--Idaho State University (2023)

This dissertation describes strategies instructional designers can use to foster essential processing when designing multimedia instruction with different combinations of the use and non-use of the modality and segmenting principles described by Clark and Mayer (2016). This study investigated the main effects of segmenting and modality, and different combinations of the use and nonuse of the modality and segmenting principles, on recall and transfer test scores on gear instruction. The results from this study provide insight into how the use of one or more principles impacted overall, recall, and transfer learning outcomes.

The results of the study revealed a lack of significant main effects for modality and segmenting on the overall, recall, and transfer posttest scores. Furthermore, there were no statistically significant differences observed among the four groups: control, modality, segmenting, and segmenting & modality. These findings suggest that the utilization of modality and segmenting principles did not improve learning outcomes compared to not using any principle, and employing both principles together did not yield superior results compared to using modality or segmenting alone. These results are inconsistent with a considerable body of prior research; however, they do not imply disregarding all previous research in the field.

It should be noted that the sample size consisted of only 71 participants, which was a small sample size. The brevity of the treatment duration and the presence of ceiling effects may have influenced the findings of this research. The observed ceiling effects can potentially be attributed to several factors, including the simplicity of the test items used in the instrument,

administering the instrument immediately after the instructional intervention, the effectiveness of the instructional intervention itself, and participants' existing knowledge prior to the study.

Future studies could utilize a larger sample size, select more complex instructional topics, and incorporate more rigorous instruments. These improvements would have facilitated a more accurate assessment of the impact of the modality and segmenting principles on learning outcomes. Moreover, exploring the effect of the modality and segmenting principles on delayed transfer would have provided valuable insights into their long-term effectiveness in promoting knowledge retention and transfer.

Key words: cognitive load theory, cognitive theory of multimedia learning, essential processing, e-learning, multimedia principles, modality principle, segmenting principle

CHAPTER I

Introduction

Purcell et al. (2013) stated that current and past instruction in education differs in many ways. This author went on to say teachers have recently adopted technology uses and solutions that allow students to engage in digital and other new forms of learning. Fletcher and Tobias (2005) described that instructors and learners today likely use tools such as Smartboards, eLearning, Zoom, webcams, learning management systems (LMS), online forum discussions, and Google Docs. Prensky (2001) noted that these technologies are included in the broad field of multimedia because they allow or use text, graphics, animation, and sound to deliver information. Mayer (2021) stated that using these technologies met the definition of multimedia since they allowed the presentation of information using both words and pictures to promote learning.

Using multimedia has become frequently used to make traditional face-to-face classes more interactive (Li et al., 2013). For example, Liu and Elms (2019) and Mandernach (2009) found that students felt more engaged when multimedia presentations were added to classroom content compared to traditional lecture lessons. In addition to increasing engagement, multimedia presentations improved learners' problem-solving skills, learning outcomes, memory skills, and motivation for learning (Li et al., 2013; Liu et al., 2009; Neo & Neo, 2010). Other researchers have found that a well-designed and interactive multimedia experience engages learners, increases recall, and improves learning outcomes (Alessi & Trollip, 2001; Mayer, 2021; Neo & Neo, 2010). However, to better use multimedia in teaching, instructional designers should understand cognitive theory related to multimedia learning (Alessi & Trollip, 2001).

Sweller (1994) stated that instructional designers might not effectively use instructional technologies and environments without theoretical foundations. This author showed an example to support this idea: instruction can be full of images, text, animations, and hyperlinks to improve learning engagement. However, combining several media types could distract learners, leading to visual cognitive overload. Therefore, instructional designers can design resources to guide learners effectively, they can manipulate content and media types to meet learners' needs by recognizing the cognitive load induced by items on pages (Paas et al., 2003).

Clark and Mayer (2016) explained a leading theory on multimedia learning called the cognitive theory of multimedia learning (CTML). Mayer (2014) stated that CTML builds on several criteria: theoretical plausibility, testability, empirical plausibility, and applicability. Mayer also explained these criteria in detail; theoretical plausibility means that the theory aligns with contemporary cognitive science principles. Furthermore, testability suggests that predictions can be scientifically tested while empirical plausibility indicates that the theory is consistent with other empirical research on multimedia learning. Finally, applicability shows the theory's importance in improving multimedia learning content (Mayer, 2014).

CTML emerged from three theories: dual channel processing (DCP), cognitive load theory (CLT), and active processing (Moreno & Mayer, 1998). Among these theories, the dual-channel assumptions are based on Paivio's (1991) dual-coding theory and Baddeley and Hitch's (1974) working memory model. The dual-channel assumption indicates that learners process information through two channels in their brains: the visual channel for visual, spatial, and nonverbal information and the auditory channel for auditory and verbal information (Mayer, 2014; Mayer & Moreno, 2003; Paivio, 1991). CTML uses a hybrid approach to distinguish visual and auditory materials, with visual materials defined as pictures, animation, video, and onscreen text.; In contrast, the auditory channel processes materials defined as narrative and background sound (Mayer, 2014). According to cognitive load theory, each channel can only process a limited number of materials simultaneously (Meyer, 2014; Sweller et al., 2011). The average person's memory span is typically five to seven pieces of information at once (Mayer, 2014; Miller, 1956; Schnotzet al., 2014). The active processing assumption refers to learners' cognitive processing that helps them understand information (Mayer, 2014).

Instructional animation can be regarded as multimedia, requiring visual and auditory interaction from learners (Mayer, 2014). This form of animation can also be regarded as a dynamic visual representation of an event or process (Mayer & Chandler, 2001). In addition, instructional animation conveys information through apparent motion, such as information associated with procedures (Narayanan & Hegarty, 2002). Some researchers have found that dynamic information in animations may require additional cognitive processing (Hegarty et al., 2003; Spanjers et al., 2011; Tversky et al., 2002). Furthermore, when people view animation, many tend to focus their visual attention only on one event happening in the animation and ignore other events (Hegarty et al., 2003). To address these problems and make the design of instructional animations beneficial to learners, instructional designers should use the multimedia principles that manage essential processing: modality, segmenting, and pretraining (Clark & Mayer, 2016; Mayer, 2021; Mayer & Moreno, 2003).

The pretraining principle includes providing advanced guidance on crucial parts of the material that helps students learn (Clark & Mayer, 2016). The modality principle involves using audio rather than onscreen text and images to improve learning (Mayer, 2021). Finally, the segmenting principle comprises that presenting content in smaller amounts is more conducive to learning than contiguous content (Mayer & Moreno, 2007). This study is related to the modality and segmenting principles, which have been shown as valid by many studies.

The modality principle states, “people learn more deeply from pictures and spoken words than from pictures and printed words” (Mayer, 2021, p.281). This author noted that when both on-screen text and images enter the cognitive system in the visual channel, an overload in this channel may occur. Conversely, if the instructional video uses narration instead of on-screen text, the words will be processed in the verbal channel, allowing learners to process the images in the visual channel. Many studies have shown that using modality with instructional animation improves students' learning performance (Atkinson, 2002; Ioannou et al., 2017; Mayer & Moreno, 1998; Mousavi et al., 1995). Students can process and learn more effectively with instruction that uses the modality principle because the information presented in both visual and auditory modes is less likely to overload working memory (AbuSaada et al., 2013; Aldalalah et al., 2010; Dubois & Vial, 2000; Harskamp et al., 2007; Moreno & Mayer, 1999; Moreno et al., 2001; Tindall-Ford et al., 1997).

Mayer (2021) defined segmenting as “people learn better when a multimedia message is presented in user-paced segments rather than as a continuous unit” (p.247). The author provided an example of a continuous version of animation on 16 steps of lightning formation lasting about two and half minutes. If the segmenting principle is applied to this instruction, the lesson would be broken into smaller segments, each with a continue button that allows some consideration of the content and then provides access to the next segment (Mayer, 2021). A number of studies have found that students can better remember and apply what they have learned when using the segmenting principle in instruction (Hasler et al., 2007; Mayer et al., 2003; Mayer et al., 2018; Mayer & Chandler, 2001; Mayer & Pilegard, 2014; Moreno, 2007). This is because the segmented materials help prevent students from overloading their working memory while engaging with the instructional materials (Ayres, 2006; Boucheix & Schneider, 2009; Chung et al., 2015; Hassanabadi et al., 2011; Lusk et al., 2009; Spanjers et al., 2011; Stiller et al., 2009).

Several studies have shown consistent outcomes for the modality and segmenting principles, but few researchers have combined these two principles in studies (Cheon et al., 2014; Daley, 2023; Dousay, 2016). Instructional designers could consider whether the two principles can be combined to achieve better instruction (Cheon et al., 2014). Similarly, some researchers have proposed the modality and segmenting principles as ways to overcome the cognitive overload from animation (Ayres & Paas, 2007; Hasler et al., 2007; Mayer, 2021; Mayer & Moreno, 2003). This study's literature review will provide more explanation regarding combining these principles.

Statement of the Problem

As mentioned above, CTML provides principles to guide instructional designers in creating lessons with textual, graphical, video, and audio information for optimal learning (Clark & Mayer, 2016). The modality principle, based on the dual-channel assumption, holds that people learn better when visual and auditory inputs are combined, while the segmenting principle asserts that learning can be improved by breaking information or lessons into parts (Mayer, 2014). Cheon et al. (2014) mentioned both principles aim to increase the efficient use of cognitive resources by managing the learner's short-term memory load during learning. However, some researchers' conclusions about the segmenting principle may oppose the modality principle because segmental animation could allow learners to process both animation and text without cognitive overload (Cheon et al., 2014). However, many questions remain regarding the use of both principles together (Clark & Mayer, 2016; Hassanabadi et al., 2011;

Singh et al., 2012; Stiller et al., 2009). Although the CTML includes concepts regarding both principles and how they might be used, the CTML does not specify whether either principle is more effective. Moreover, the theory contains no consideration of whether the two principles working together can better improve learning than either alone.

Purpose of the Study

The purpose of this study will be to examine the influence of the CTML on students' learning performance in a lesson about gear systems. In this study, student learning will be examined using the modality and segmenting principles independently and combined to determine if these principles used jointly allow improved learning of the course content over using only one principle.

Research Questions

1. Is there a statistically significant main effect of using the modality principle in electronic instruction on students’ overall test scores on gear systems over not using modality?
   - 1.1. Is there a statistically significant main effect of using the modality principle in electronic instruction on students’ recall test scores on gear systems over not using modality?
   - 1.2. Is there a statistically significant main effect of using the modality principle in electronic instruction on students’ transfer test scores on gear systems over not using modality?
2. Is there a statistically significant main effect of using the segmenting principle in electronic instruction on students’ overall test scores on gear systems over not using segmenting?

2.1. Is there a statistically significant main effect of using the segmenting principle in electronic instruction on students' recall test scores on gear systems over not using segmenting?

2.2. Is there a statistically significant main effect of using the segmenting principle in electronic instruction on students' transfer test scores on gear systems over not using segmenting?

3. Are there statistically significant interaction effects of using different combinations of modality and segmenting principles on students' learning?

3.1. Does using the segmenting principle alone improve overall learning versus using neither principle?

3.1.1. Does using the segmenting principle alone improve recall learning versus using neither principle?

3.1.2. Does using the segmenting principle alone improve transfer learning versus using neither principle?

3.2. Does using the modality principle alone improve overall learning versus using neither principle?

3.2.1. Does using the modality principle alone improve recall learning versus using neither principle?

3.2.2. Does using the modality principle alone improve transfer learning versus using neither principle?

3.3. Is there a difference between students' overall learning when taught with the modality principle alone versus the segmenting principle alone?

3.3.1. Is there a difference between students' recall learning when taught with the modality principle alone versus the segmenting principle alone?

3.3.2. Is there a difference between students' transfer learning when taught with the modality principle alone versus the segmenting principle alone?

3.4. Does using both the segmenting and modality principles together increase overall learning compared to segmenting alone?

3.4.1. Does using both the segmenting and modality principles together increase recall learning compared to segmenting alone?

3.4.2. Does using both the segmenting and modality principles together increase transfer learning compared to segmenting alone?

3.5. Does using the segmenting and modality principles together increase overall learning compared to modality alone?

3.5.1. Does using the segmenting and modality principles together increase recall learning compared to modality alone?

3.5.2. Does using the segmenting and modality principles together increase transfer learning compared to modality alone?

Definition of Terms

- **Control group:** According to Kothari (2004), "The control group is used as a standard for comparison with the experimental group or treatment group in order to assess the effectiveness of the treatment" (p. 167). This allows researchers to isolate the effects of the independent variable (the treatment or intervention being tested) on the dependent variable being measured, while controlling for extraneous variables that may affect the results.

- **Gear system:** A gear system is a mechanical system that consists of two or more interlocking gears that transmit motion and power from one shaft to another. According to Colbourne (2012), gears are the fundamental means by which power is transmitted from one rotating shaft to another. The gears in a gear system are typically circular or cylindrical objects with teeth along the edges that mesh together and transfer rotational force. The primary purpose of a gear system is to change the speed, torque, or direction of rotation of a power source to a different output speed, torque, or direction.
- **Anticlockwise:** Anticlockwise, also known as counterclockwise or counter-clockwise, refers to the direction opposite to the clockwise direction. This term is commonly used in various fields such as physics, engineering, and mathematics to describe the direction of torque or angular velocity (Young & Freedman, 2016). For the purpose of this study, the term anticlockwise will be used instead of counterclockwise.
- **Cognitive Theory of Multimedia Learning (CTML):** CTML includes principles to guide designers of multimedia and e-learning in the presentation of textual, graphical, video, and audio information for optimal learning (Clark & Mayer, 2016).
- **Information-Processing Theory (IPT):** Information-processing theory is aimed to explain the process of acquiring, processing, storing, and retrieving information from memory and guides how memory can be enhanced (Miller, 1956).
- **Working Memory Model:** Working memory model describes how information is retained. According to this model, working memory is an element of a multi-

part system, and each element is responsible for discrete functions. Each part of the system can only process limited information, and the components and their functions are more or less independent of the others (Baddeley & Hitch, 1974).

- **Dual-Coding Theory:** Dual-coding theory regards human cognition as unique because it has become specialized for dealing simultaneously with language and nonverbal objects and events (Paivio, 1991).
- **Dual-Channel Processing (DCP):** Dual-channel processing is an assumption that human brains have separate pathways or channels and anatomical regions channels for processing visual and auditory information (Mayer, 2021).
- **Cognitive Load Theory (CLT):** Cognitive load theory holds the assumption that working memory is limited in both duration and capacity (Plass et al., 2010). Thus, instruction should be designed to reduce the working memory load to promote learning.
- **H5P:** H5P (HTML5 Package) is an open-source technology for creating and sharing interactive content on the web. H5P allows users to create and publish interactive content such as quizzes, games, interactive videos, and presentations, using a variety of multimedia elements such as images, videos, and audio (H5P, n.d.).
- **Ceiling Effect:** A ceiling effect occurs when most participants in a study or the data points in a dataset reach the highest possible score or value on a particular measurement or assessment (Maxwell et al., 2017). In such cases, the measure or task lacks the sensitivity to capture distinctions among high-performing individuals, resulting in limited variability in the upper range of scores or values.

> This can hinder researchers' ability to differentiate between participants with higher levels of the measured attribute, potentially leading to inaccurate conclusions or reduced statistical power in their analyses (Maxwell et al., 2017).

Limitations

Campbell and Stanley (1963) described eight challenges to internal validity from variables. These challenges are history, maturation, testing, instrumentation, statistical regression, differential selection, experimental mortality, and selection-maturation interaction. Cook and Campbell (1979) added four additional challenges to this foundation: experimental treatment diffusion, compensatory equalization of treatment, compensatory rivalry by the control group, and resentful demoralization of the control group. These challenges are discussed in the research design of this study.

History

History is defined as unexpected events that may have occurred within the study's time frame (Campbell & Stanley, 1963). For example, in the current study, 1 to 2 weeks could elapse before the participants receive instruction for the test. During this time, participants are not observed or under controlled conditions. It is possible that participants’ abilities and knowledge may be altered by various extra-curricular activities, access to the library, coaching from the writing center, and other activities unrelated to the treatment prior to the posttest. For this reason, the researcher will randomly assign the participants to their treatments which mitigates this limitation.

Maturation

Maturation occurs when the study outcomes vary naturally over time (Campbell & Stanley, 1963). Participants were in the study for 1 to 2 weeks, a reasonable time for learning the first unit of the simple machine course. At the same time, the learners will be tested immediately after they finish the course. In other words, participants will not have much opportunity to gain more knowledge before the posttest, thus minimizing the threat of this limitation to the research.

Testing

Testing occurs when the pretest influences the outcomes of the posttest (Campbell & Stanley, 1963). Participants will be tested only once, thus eliminating this potential limitation.

Instrumentation

Instrumentation refers to the differences in results that might be attributed to a lack of reliability and validity in instruments, raters, or observers (Campbell & Stanley, 1963). To demonstrate knowledge of gear systems, learners need to be able to recognize all gear components and relationships of a gear system. A posttest will assess learners' attainment of the objectives. For this reason, the assessment instrument will be examined by subject matter and design experts for content validity.

Statistical regression

Statistical regression is the mathematical tendency of measurements of extreme cases to become less extreme with repeated measurement (Campbell & Stanley, 1963). This research has only one measurement, and all participants will be randomly assigned to four groups, thus minimizing the threat of this limitation.

Differential selection

Differential selection arises when non-random methods are used for group assignment (Campbell & Stanley, 1963). All participants in this research will be randomly assigned to four groups, which differential selection will not be a threat for this research.

Experimental mortality

Experimental mortality can arise when students leaving the study are not representative of the entire sample (Campbell & Stanley, 1963). Participants that drop out of this study will be examined to determine if there is a pattern to which treatment groups are losing participants. For this reason, the random assignment of all participants in this study will reduce the potential threat of this limitation.

Selection-maturation interaction

Selection-maturation interaction is defined as the selection of comparison groups and maturation interaction which may lead to confounding outcomes and erroneous interpretations that the treatment caused the effect (Campbell & Stanley, 1963). Because the study includes random assignment to groups, the group allocation has no relationship with the characteristics of the participants. Also, the short duration of the study will limit the amount of maturation the subjects may experience.

Experimental treatment diffusion

Experimental treatment diffusion occurs when participants in the different treatment groups communicate with each other, and participants in the various groups can learn information intended for one specific group (Cook & Campbell, 1979). All participants will be in a lab setting, wearing headphones for less than 30 minutes of instruction while being observed by the lab assistant. Therefore, there will be little opportunity for diffusion to occur. This design minimizes the threat of this limitation.

Compensatory equalization of treatment

Compensatory equalization of treatment appears when inequality exists due to the experimental group receiving treatment (Cook & Campbell, 1979). As mentioned above, the content of all instructional videos used in this research is the same; the only difference is the way videos are presented. The threat of this limitation will be minimized because of this design.

Compensatory rivalry by the control group

Compensatory rivalry by the control group occurs when participants are made aware of who has been assigned to each group, and the control group participants might feel disadvantaged and work harder to minimize the difference (Cook & Campbell, 1979). The list of participants in each research group is confidential and only known to instructors in each course and the researcher. Therefore, this design will minimize the threat of this limitation.

Resentful demoralization of the control group

Resentful demoralization of the control group arises when the participants in the control group become resentful and demoralized because they feel they receive less desirable treatment than the other groups (Cook & Campbell, 1979). The content of all the instructional videos in this research is the same, but the only difference is the way of presentation. Also, participants will not be told about their group assignment before the study. Thus minimizes the threat of this limitation to this research.

Delimitations

According to the study of Bracht and Glass (1968), twelve factors affecting external validity were analyzed from the perspectives of population and ecological validity. Each factor will be discussed first and then together with the research design.

Experimentally accessible population vs. target population

The delimitation of experimentally accessible population versus target population limits generalizability if the experimental group's results are generalized to the population when the sample group doesn’t represent the whole population (Bracht & Glass, 1968). The target population of this research is students at a medium-sized university in the Intermountain West. This study will report the demographics of the sample in Chapter 4. Therefore, the audience can decide for themselves whether the results of the study may apply to their population.

Interaction of personological variables and treatment effects

Interaction of personological variables and treatment effects occur when participant traits limit the generalizability of study findings to larger populations because of differences between the sample and target groups (Bracht & Glass, 1968). All participants will be randomly assigned to ensure that participants' personological variables are evenly distributed across all groups to reduce the threat of this delimitation.

Describing the independent variable explicitly

This threat appears when independent variable descriptions are not well-detailed in the study's experimental design or are omitted so the study cannot be replicated (Bracht & Glass, 1968). Researchers need to communicate all aspects of the treatment(s) and the experimental setting, precondition for generalizing and replicating the experiment (Bracht & Glass, 1968). In this research, the modality and segmenting principles are the two independent variables, each with two levels, use, and non-use. Using the modality principle will result in an instructional video consisting of visual elements and audio narration. Not using the modality principle will result in an instructional video that has visual elements with onscreen text. Using the segmenting principle will result in instruction that is broken into smaller segments. Not using the modality principle will result in a longer, continuous instructional video. By defining the independent variables, and their levels, this delimitation should be avoided.

Multi-treatment interference

Multiple-treatment interference may occur when subjects are exposed to several treatment conditions such that the experimenter cannot isolate any specific condition as the cause for change (Bracht & Glass, 1968). In this study, all participants will be randomly assigned to receive only one treatment. This eliminates the threat of multi-treatment interference delimitation.

Hawthorne effect

The Hawthorne Effect occurs when participants' behaviors are influenced by their perception of the treatments and cause behaviors that would not occur otherwise (Bracht & Glass, 1968). All participants will be randomly assigned to one of four treatment groups without knowledge of which group they are in. In addition, the subjects will participate in only one instructional instance. These two research design factors will reduce the potential impact of this delimitation.

Novelty and disruption effects

Novelty and disruption effects linked to the uniqueness or novelty of the treatment could influence the findings (Bracht & Glass, 1968). The content of the treatment will be independent of students' courses, which will eliminate the disruption between students' courses and treatment. As the lab will be a new environment for all participants, the novelty effect should be the same for all participants. This design will reduce the novelty and disruption effects.

Experimenter effect

The experimenter effect develops when the characteristics, behaviors, or expectations of the experimenter influence the participants' behavior (Bracht & Glass, 1968). All participants will be in a lab setting while being observed by the lab assistant. The lab assistant is only responsible for the management of lab orders but is not directly involved in treatment. The instructional method of this study will only use an instructional video to teach the students, so there will be no instructor involvement in this instructional method. This setup minimizes the threat of the experimenter effect.

Pretest sensitization

Pretest sensitization occurs when a pretest affects a participant's subsequent responses to experimental treatments (Bracht & Glass, 1968). There is no pretest in this research, which minimizes the threat of this delimitation.

Posttest sensitization

Posttest sensitization happens when the posttest becomes an added learning experience and gives false positive results from the treatment (Bracht & Glass, 1968). All participants will be randomly assigned to one of four groups and given the same posttest. Therefore, all participants will have equal access to the content of the test, which should reduce the threat of posttest sensitization.

Interaction of history and treatment effect

Several potential historical events have the potential to interact with the treatment effect, such as emotion-packed events, unusual student moral conditions, and local or national political events (Bracht & Glass, 1968). All participants will be randomly assigned to one of four groups to distribute historical effects evenly. This design minimizes the threat of this delimitation.

Measurement of the dependent variable

Measurement of the dependent variable concerns the ability to generalize the results and is contingent on the dependent variables and the instruments used to measure these variables (Bracht & Glass, 1968). The design of the posttest will be based on the instructional objectives of the study. The content of the posttest will be examined by professionals to provide some content validity evidence before using it in this research. All these operations will reduce the threat of this delimitation.

Interaction of time of measurement and treatment effects

The interaction of time of measurement and treatment effects occurs when the results from the measurement of the dependent variable are limited to the time of its measurement (Bracht & Glass, 1968). All participants will take a posttest immediately after completing the instruction to ensure there is no significant time gap between measurement and treatment. This will reduce the impact of time as part of this delimitation.

Significance of the study

Stiller et al. (2009) reported that segmenting and modality improved transfer test performance when the words were printed but produced only a slight effect when they were spoken. In contrast, Hassanabadi et al. (2011) showed that segmenting with modality improved transfer test performance when the words were spoken but produced a much smaller effect when they were printed. Furthermore, Singh et al. (2012) reported that segmenting with modality was beneficial for lessons with spoken text and printed text, but the most significant benefit was with spoken text, maybe because of the transitory nature of long-spoken text passages. All in all, the extant studies are insufficient to determine whether the advantage of segmenting with modality in instruction has similar effects on lessons involving narration or printed text. This also supports the importance of this research in instructional design.

CHAPTER II

Literature Review

This literature review begins with an overview of the types of knowledge transfer. This overview is followed by a discussion of multimedia learning, including design principles and their effects on essential, generative, and extraneous cognitive processing. After the discussion on multimedia learning, this study focuses on reviewing the use of the modality and segmenting principles in previous research. Additionally, studies that included more than one multimedia principle are reviewed.

Types of Transfer

Glick and Holyoak (1987) identified several types of transfer learning that are categorized into three dimensions. The first dimension includes positive, negative, and zero transfer. The second dimension comprises near and far transfers. Finally, the third dimension addresses lateral and vertical transfer. In the first dimension, the positive transfer is defined as "the improvement or embellishment of current knowledge through the gain of additional information or education" (Glick & Holyoak, 1987, p.36), which occurs when knowledge learned in one situation benefits learning in another. For example, Mautone and Mayer (2001) showed that positive transfer occurred when students increased scores on problems requiring transfer when the narrator emphasized keywords and phrases in the instruction. As the opposite of positive transfer, the negative transfer is defined as knowledge learned in one situation interfering with learning in another situation (Glick & Holyoak, 1987). For example, Mayer, Sobko, and Mautone (2003) found that when native English speakers were taught by multimedia narrated with a foreign accent, the problem-solving transfer scores decreased. Finally, zero transfer is when learning in one situation does not affect learning in another (Glick & Holyoak, 1987).

Near transfer refers to the transfer between two situations or tasks that are similar in their superficial and underlying characteristics and principles (Glick & Holyoak, 1987). For example, Royer (1979) found that after students have learned two-digit addition, they could apply their knowledge of two-digit addition to three-digit addition situations. Unlike near transfer, far transfer refers to the transfer between two situations or tasks dissimilar in their superficial and underlying characteristics (Glick & Holyoak, 1987). Royer (1979) gave an example of far transfer: a student applying their additional knowledge to solve word problems about buying multiple items without prompting.

Lateral transfer is the application of knowledge or skills between tasks or problems of similar complexity (Glick & Holyoak, 1987). Lee et al. (2006) stated that lateral transfer occurs when students understand that 4 times 9 equals 36 is conceptually equivalent to 9 times 4 equals 36. A vertical transfer is the transfer of knowledge or skills from a less complex task to a more complex task (Glick & Holyoak, 1987). For example, in a study by Gagné and Paradise (1961), students who learned addition could understand multiplication more easily than students who learned multiplication first.

Mariano (2014) stated that the three transfer dimensions might coincide because they all incorporate knowledge transfer among similar pieces of knowledge. An example from Mariano's study, after students learned the cause of lightning, they successfully transferred this to a problem regarding how to reduce the likelihood of lightning strikes. In this example, positive, near, and lateral transfers coincided.

Cognitive Theory

Lohr and Gall (2008) mention as many more technologies are used in instruction, educators are beginning to seek increasingly effective media designs. Therefore, media designs continue to progress for these teaching requirements, and many of these advances are due to the influence of cognitive processing theories (Lohr & Gall, 2008). Wittrock (1979) considered instruction an art, beginning with understanding and diagnosing the learner's cognitive and emotional processes. To follow this suggestion, an understanding of how instructional strategies and materials impact learners' attention, motivation, and understanding will be important, and many instructional theories can help us understand how multimedia design can be used as a learning strategy (Mayer et al., 2001; Lohr & Gall 2008).

Information-Processing Theory (IPT)

Information-Processing Theory (IPT) is a theory founded by Atkinson and Shiffrin (1968); they proposed a model depicting short-term and long-term memory. Atkinson and Shiffrin stated that when the senses record new information, the details of the information are transferred to short-term memory for processing and assimilation. Short-term processing culminates in storage in long-term memory for retrieval and user. However, Baddeley and Hitch (1974) thought the memory process explained by IPT is far too simple. According to the IPT, short-term memory holds limited information for a relatively short period with little processing relative to other system levels. These short-term processes consist of a unitary system without subsystems. For this reason, Baddeley and Hitch (1974) proposed a working memory model. In this model, working memory is regarded as short-term; however, instead of all information going into one short-term memory, working memory consists of subsystems for different types of information. In other words, working memory is a multi-component system in which auditory and visual information are processed separately.

Dual-Channel Processing

Paivio (1991) proposed a similar theory suggesting two separate memory systems: the oral and visual systems. This theory is known as the dual-coding theory. The working memory model described how information is processed in separate channels for processing visual and auditory information (Baddeley & Hitch, 1974). Consistent with the working memory model, Paivio suggested separate channels for processing visual and auditory information. While the working memory model is focused on dual channels for visual and auditory information, the dual-coding theory includes distinct channels for verbal and non-verbal information. Clearly, these two models include different interpretations of dual channels. Mayer (2021) considered a compromise between these two models and particularly an understanding of independent channels with dual-channel processing. Mayer supposed that dual-channel processing includes humans having two separate channels which process auditory and visual information. In this assumption, visual materials can be pictures, animations, videos, and onscreen text. Auditory materials can be narrative and background sounds.

Cognitive Load Theory

Cognitive load theory states that individuals have a limited capacity to process information (Sweller, 1994). This author suggests that learners must complete the assignments with whatever cognitive capacity they have; therefore, instruction should be designed to prevent working memory from becoming occupied by unnecessary information or processes (Sweller, 1994). Sweller et al. (2011) categorized cognitive load into intrinsic, germane, and extraneous loads. Intrinsic load refers to the inherent complexity of the task being performed and is associated with the amount of information that must be processed; it is an inherent characteristic of the task and cannot be reduced. Germane load refers to the mental effort required for the development of schema or long-term memory structures, and it is necessary for the formation of durable and useful knowledge. Extraneous load refers to any load that is not intrinsic to the task or germane to the learning process. It can be created from various sources such as poor instructional design, distractions, or irrelevant information. Therefore, an educator should limit extraneous load. As long as external, internal, and germane loads do not exceed the working memory capacity, some working memory remains available for processing (Sweller et al., 2011).

Cognitive Theory of Multimedia Learning

Using these theories, Mayer et al. (2001) integrated results from research and proposed the CTML. These authors attempt to explain how humans learn in multimedia environments. They focused the theory on how humans process information in working and long-term memory for meaningful learning experiences in a multimedia environment. CTML incorporates 12 specific multimedia principles, classified according to three instructional goals. These three goals are reducing extraneous, fostering generative, and managing essential processing (Mayer, 2014). Mayer formulated five steps for reducing extraneous processing: coherence, signaling, redundancy, spatial contiguity, and temporal contiguity principles. The coherence principle recommends removing extraneous information from instruction. The signaling principle is about allowing learners to find what they should attend to during instruction. The redundancy principle includes that audio and images combined are better than using audio, text, and images independently. The spatial contiguity principle regards using images displayed closely with relevant textual explanations in instructional materials. The temporal contiguity principle suggests that images should be presented with corresponding narratives.

The following two principles foster generative processing; the personalization principle concerns using informal or conversational voices in instruction, and the voice principle supports using human voices rather than computer voices. Finally, three principles are linked to managing essential processing, the pretraining principle, the modality principle, and the segmenting principle. Instructors can use the pretraining principle to inform learners about fundamental knowledge before giving additional instruction. The modality principle is about using visual and verbal narratives rather than visual and printed text in instruction. Instructors use the segmenting principle to present information in segments rather than a continuous stream (Mayer, 2014).

Modality Principle. Mayer and Moreno (1998) found that instructors could more effectively explain the operating procedure of a car's braking system using the modality principle. In this study, students were assigned to two groups, each receiving a different type of treatment. The first group was simultaneously presented with animation and audio narrations, and the second group was presented with animation and onscreen text. After the treatment, both groups were given retention, matching, and transfer tests. Results showed that the group receiving animation and audio narrations simultaneously performed better than the group that viewed animation and onscreen text in all three tests. Therefore, auditory information is much more effective than an onscreen text explanation when simultaneous graphic materials accompany auditory input.

In a follow-up study, Moreno and Mayer (1999) found a similar outcome for instruction about how lightning forms. Students were placed into two groups with two different treatment modes, which explain the steps in lightning formation. The first group was given the animations and audio narrations concurrently, while the second group was given the animations with onscreen text. At the end of the experiment, students were also given retention, matching, and transfer tests. Results showed that the audio narration group performed significantly better than the onscreen text group on all tests. These results indicated that multimedia learning with animations and narration of explanation is much more effective than onscreen text explanation. The drawbacks of the onscreen text can also explain this result; for example, Mayer's CTML predicts that onscreen text explanation could create an overload in the visual processing channel (Clark & Mayer, 2016; Mayer & Moreno, 1998).

Mousavi et al. (1995) taught geometry with the modality principle to mathematics students and obtained similar results. Three groups of students were formed and presented with different geometry examples. The first group was presented with diagrams, text, and narrations. The second group received only diagrams and text. Finally, the third group was given diagrams and narrations. The results showed that learning was comparatively better when the narration was included with the diagram and text. The researchers suggested dual-presentation modalities may have optimized the working memory by tapping into auditory and visual working memory processes rather than one channel (Mousavi et al., 1995).

Atkinson (2002) also researched the modality principle with mathematics students. The study tested this principle regarding the complexity of solving algebra problems that require multiple steps. In this experimental study, students were placed in five distinct algebra learning environments. These environments were narration only, text only, text with dynamic visuals, text with static visuals, and narration with dynamic visuals. The results showed students in groups that include narration are better at solving algebra problems. This outcome showed a modality effect that occurs while learning algebra (Atkinson, 2002).

Ioannou et al. (2017) explored the modality principle when teaching mathematics at the primary school level. The lessons concerned triangles, and students were randomly assigned to two groups, each using one of two modes. The first mode consisted of pictures with narration and the second comprised pictures with onscreen text. Results showed that the student groups given the pictures and narration performed better than those with pictures and onscreen text. In other words, students learn better when triangle lessons were presented with images and accompanied by narration explanations than with only onscreen texts (Ioannou et al., 2017).

Some researchers studied the effects of the modality principle on learning biology; for example, Harskamp et al. (2007) used two experiments to explore whether the modality principle holds in biological science lessons. In the first experiment, 27 students aged 16 and 17 were placed into two groups, and each group was given a treatment mode for a web-based multimedia lesson. Group one received the animation plus narration mode, and the second group received animation with onscreen text. In a second experiment, 55 students aged 16 and 17 were separated into two groups and given the same treatments as the first experiment. Results showed that the first group outperformed the second group in the transfer test in both experiments. This result means a modality effect occurred when teaching biology in school for students aged 16 and 17 (Harskamp et al., 2007).

Moreno et al. (2001) explored the modality principle using a botany game in a higher education setting. Sixty-four college students were placed into groups with different treatments during instruction. These treatments included images with text, images plus narration, text with no images, and narration without images. These groups were tasked with designing plants' roots, stems, and leaves for survival in different environments. The results revealed that the image with narration group performed better than the image with text group, and the no-image with narration group performed better than the no-image with text group on all tests. The results showed that students performed better on retention and problem-solving transfer tests when content was presented as speech rather than onscreen text (Moreno et al., 2001).

Tindall-Ford et al. (1997) studied the learning of electrical engineering concepts using the modality principle. Students were grouped into treatment conditions of visual presentation with audio and visual information with onscreen text. The outcomes showed that students learned better when instructions were in both visual and audio compared to only onscreen text. These visual instructions can be given as table diagrams or both and accompanied by a concurrent audio narration (Tindall-Ford et al., 1997).

For foreign language learning, Aldalalah et al. (2010) also found modality effects when learning Arabic. Two treatment modes were used for 123 students carefully selected from IRBED Jordan Education Directorate. The first treatment model was the combination of audio with images, and the second treatment mode was the combination of text with images. The results showed that learners using the audio with images mode performed significantly better than those using text with images. Therefore, the result agrees with the modality principle theory regarding the addition of audio narrations improving learning more than onscreen text in instruction (Aldalalah et al., 2010).

In another language learning experiment, Dubois and Vial (2000) used four different multimedia presentation modes to explore the modality effects on Russian vocabulary learning. Sixty college students were randomly assigned to one of the four multimedia presentation modes. In mode one, students read and listen to the Russian words and pronunciation while reading a translation in French. In mode two, images were added to illustrate the direct meaning of the word. In mode three, the image was edited to visualize the link between the Russian word, and a sentence was stated to introduce the picture. Finally, the pronounced sentence was changed to onscreen text in this last mode. The results showed that students receiving the mode three treatment outperformed the other modes, and this outcome agrees with the modality principle (Dubois & Vial, 2000).

Fiorella et al. (2012) investigated the modality principle of instructional design in simulation-based training environments. Sixty total students were assigned to either the spoken-text feedback group, printed-text feedback group, and no feedback group. The results indicated that the spoken-text feedback group's performance on decision-making during training and assessment exceeded those who received the printed-text feedback group. Also, students who learned in the spoken-text feedback group applied their decision-making knowledge better than both other groups. These findings supported the applicability of the modality principle to the presentation of real-time instructional interventions and the acquisition and application of higher-order cognitive skills (Fiorella et al., 2012).

The modality effect also occurred during adult training; in this experiment, two different video streaming modes were used in the International Council on Development and Learning (ICDL) course for trainee teachers (AbuSaada et al., 2013). Two hundred teachers were assigned to one of two groups, one with video-narration mode and another with video-text mode. After the instruction, the teacher participants were tested. The results showed that the teachers in the video-narration mode demonstrated significantly higher achievement than those taught using the video-text mode, and those with video-narration mode learned better and deeper than the video-text mode teachers. This suggests that information presented in visual and auditory modes was less likely to overload working memory, so some working memory capacity was available for information processing, and thus outcomes improved (AbuSaada et al., 2013).

Moreno and Mayer (2002) experimented with the effects of the modality principle in virtual reality environments. Eighty-nine students were assigned to the following groups: narration with a desktop display, text with a desktop display, narration with a head-mounted display, text with a head-mounted display, narration and head-mounted displays plus walking, and text with a head-mounted display plus walking. The results showed that students who learned with narration in all contexts outperformed those who learned with onscreen text on tests. Also, students who learned in head-mounted display conditions reported a higher sense of presence than those who learned on the desktop. These results support the modality principle as an effective instructional method in virtual reality environments (Moreno & Mayer, 2002).

Chuang and Ku (2011) examined a modality effect on learning Chinese characters. They obtained a neutral result. Sixty-eight English-speaking undergraduate students without knowledge of Chinese characters were placed in two different learning modes. The first model was presented as animated images and onscreen texts, and the second model was presented as animated images and narration. The results showed that both learning modes could help non-native learners learn Chinese characters (Chuang & Ku, 2011).

Some studies demonstrated results that conflict with the modality principle. For example, McNeill et al. (2009) investigated the modality effects in a training program. Fifty-six students participated in one of three groups and were presented with three multimedia treatment modes. Students in the first group were shown a graphic with audio narration. Students in the second group were shown graphics with onscreen text. Students in the third group were shown graphics, audio narrations, and onscreen text at the same time. The results showed no significant difference in all three groups using three different learning modes on the modality effect (McNeill et al., 2009).

Tabbers et al. (2004) found that the modality effect can be diminished by minimizing visual text by reducing sentence length. This means shorter sentences might decrease the likelihood of the modality effects. Also, controlling the pace of the presentation materials might eliminate the modality effects as well. Consistent with these findings, Tabbers (2002) showed that narrative descriptions written in brief and concise text, such as journal articles, could be as effective as verbal explanations (Tabbers et al., 2004).

Oberfoell and Correia (2016) explored whether the cognitive load used in the modality principle no longer applies to contemporary learning environments. Seventy-nine undergraduate students were placed into groups; one group received a printed text with narration, and the other received printed text only. Results showed that the modality principle was ineffective for low-experience content users. Also, students who viewed a PowerPoint presentation with only the onscreen text had more effective retention and transfer of knowledge than the students who viewed a narrated PowerPoint presentation. This indicates that the cognitive load of the modality principle may not be fully applicable to learners in some learning environments (Oberfoell & Correia, 2016).

Overall, there are three research studies indicating that using or not using the modality principle does not have a great impact on instruction (McNeill et al., 2009; Oberfoell & Correia, 2016; Tabbers et al., 2004). However, most studies pointed to two essential aspects concerning the modality principle. The first one is that using speech in audio produces better results than on screen text (Atkinson, 2002; Clark & Mayer, 2016; Harskamp et al., 2007; Ioannou et al., 2017; Mayer & Moreno, 1998; Moreno et al., 2001; Moreno & Mayer, 1999; Mousavi et al., 1995; Tindall-Ford et al., 1997). The second finding is that presenting pictures and animations as visual elements significantly reduces the distraction of learners' attention (AbuSaada,et al., 2013;

Aldalalah et al., 2010; Chuang & Ku, 2011; Dubois & Vial, 2000; Fiorella et al., 2012; Moreno & Mayer, 2002; Seufert et al., 2009). Audio narrations rather than on screen text leads to more effective learning when using animation in multimedia teaching materials. Using multimedia instruction can ameliorate the overloading of the visual channel (AbuSaada,et al., 2013; Ioannou et al., 2017; Moreno & Mayer, 1999; Wouters et al., 2009).

Segmenting Principle. Mayer et al. (2018) studied using segmenting and redundancy in an online geography slideshow. Four groups were formed from 196 student participants; the groups were non-segmented without redundancy, non-segmented with redundancy, segmented without redundancy, and segmented with redundancy. The results showed that students performed better in the segmented version of the course than in the non-segmented version, whether narration was added or not. This also means there is a statistically significant relationship between segmented and non-segmented but not a statistically significant effect for the redundant principle. Therefore, these results showed that segmenting suits learning online slide presentations of geographical content (Mayer et al., 2018).

Mayer and Pilegard (2014) found that students performed better on tests with a segmented multimedia lesson than a continuous version in 10 of 10 published experimental comparisons. Additionally, Mayer and Chandler (2001) used an animated lightning video to test the segmenting effect. Students were grouped into those receiving segmented content and a second group with continuous information. For the continuous group, students viewed a narrated animation on lightning. For the segmented group, students viewed the same lightning animation broken into 16 segments, and each segment was about 8-10 seconds long. Also, students in the segmented group had a controller with a continue button to skip to the next segment. The results showed that although both groups received identical material, students in the segmented group outscored the students in the continuous group by more than one standard deviation on a transfer test (Mayer & Chandler, 2001; Mayer & Pilegard, 2014).

In another animation experiment, Mayer et al. (2003) had students view an animation about how electric motors work with explanations from an onscreen agent, Dr. Phyz. Then, students could click on a series of questions, each presenting a segment of the same narrated animation. The results showed that students who received the narrated animation segment-by-segment performed better on a test than those who received a continuous presentation of the same material (Mayer et al., 2003).

Moreno (2007) experimented with animation to explore the segmenting principle with prospective teachers. These teachers were assigned to one of two groups and then viewed an animated lesson depicting expert teaching skills. In the first group, teachers viewed an animation broken into seven segments, and the teachers could click a button to control these segments. For the second group, teachers viewed a complete and continuous animation. The results showed that the segmented group outperformed the continuous group on a transfer test (Moreno, 2007).

Hasler et al. (2007) studied the effectiveness of using the segmenting principle in narrated animations that taught the basic principles of day and night period. Elementary school children were placed into two groups. One group of children received the lesson in segments and another group received the lesson in a continuous format. Results showed that children who received the lesson in segments performed better on a subsequent transfer test than children who received the lesson as a continuous presentation (Hasler et al., 2007).

Boucheix and Schneider (2009) used an animation about how a pulley system works to test the segmenting effect in animation instruction. College students were presented with a continuous animation or an animation broken down into steps that students could control. Results showed that the segmented group outperformed the continuous group on a transfer test with an effect size of 0.3. This result was consistent with other findings from Boucheix and Guignard (2005) involving learning content about gears.

In addition to using the segmenting principle in instruction using animation, understanding how the length of instructional segments impacts learning is of significance; Chung et al. (2015) studied the application of segmenting principle in animation instruction. In long or short pause time conditions, 176 students were assigned to a plain pause group, passive reflection group, active reflection group, passive prediction group, and active reflection group. The results showed that the reflection and prediction groups performed better than the plain pause group on the multiple-choice recall test, and the findings imply that meaningful cognitive activity during animation pauses can be beneficial. However, students in the short pause groups scored higher on an essay transfer test than those in the extended pause groups, which means long pause times may impose a cognitive load on students (Chung et al., 2015).

In addition to animation instruction, the segmenting principle has been studied with other instructional methods. For example, Lusk et al. (2009) used the segmenting principle with historical inquiry, and these authors found that segmenting can improve transfer performance for students with low working memory but not necessarily for students with high working memory. Stiller et al. (2009) found that college students who viewed a segmented lesson about the human eye outperformed those viewing a continuous lesson on a transfer test. Furthermore, Ayres (2006) and Spanjers et al. (2011) did some experiments with mathematics learners, providing preliminary evidence of more potent segmenting effects for low-knowledge students than for high-knowledge students learning from examples. Furthermore, Mautone and Mayer (2007) and

Lee et al. (2006) found that breaking complex data and graphs into parts improves performance in geoscience and chemistry.

All the above studies provide evidence that the segmenting principle can help students better remember and apply what they have learned (Hasler et al., 2007; Mayer et al., 2003; Mayer et al., 2018; Mayer & Chandler, 2001; Mayer & Pilegard, 2014; Moreno, 2007). Also, the segmented materials help prevent students from overloading their working memory while engaging with the instructional materials (Ayres, 2006; Boucheix & Schneider, 2009; Chung et al., 2015; Hassanabadi et al., 2011; Lusk et al., 2009; Spanjers et al., 2011; Stiller et al., 2009).

Two Multimedia Principles. Most of the studies above focus on using the single modality or segmenting principle in instruction, but fewer researchers have explored the simultaneous use of these two multimedia principles for instruction. Cheon et al. (2014) applied segmenting and modality principles in animated instruction. The researchers assigned students to four groups: active pauses with written text, active pauses with spoken text, passive pauses with written text, and passive pauses with spoken text. The results showed that there was a significant effect on the segmenting principle but no significant effect on the modality principle. The active pause groups were superior to passive pause groups regardless of the presentation format of the text. The student scores for the active pause group showed that active pauses were more effective than passive pauses in the animated instruction. This result could be interpreted to show that the influence of the segmenting principle in animation instruction was more significant than the modality principle, but the findings could not be interpreted to support that these principles are contradictory (Cheon et al., 2014).

Dousay (2016) examined the effects of the modality and redundancy principles of multimedia learning on the situational interest of learners. One hundred and two adult learners participated in one of the following groups: animation-text, animation-narration, and animation-narration-text groups. Results showed that the use of the modality and redundancy principles could trigger and maintain the situational interest of the learners. Also, the animations and text generated a higher situational interest in the learners than animation and narration. A surprising result was that animations, narration, and text maintained a higher situational interest than animation and narration. However, this combination of animations, narration, and written text violated the redundancy principle.

Stiller et al. (2009) reported that segmenting improved transfer test performance when the words were printed but produced only a slight effect when they were spoken. Hassanabadi et al. (2011) reported similar results; their study found that the segmenting effect was more substantial when words were spoken and not printed in a lesson about lightning for middle school students. In contrast, Hassanabadi et al. (2011) showed that segmenting improved transfer test performance when the words were spoken but produced a much smaller effect when they were printed. Furthermore, Singh et al. (2012) reported that segmenting was beneficial for lessons with spoken text and printed text, but the most significant benefit was with spoken text, maybe because of the transitory nature of long-spoken text passages.

Summary

Among all the existing literature on the modality principle and segmenting principle, most studies have shown that using the modality principle or segmenting principle alone can improve instruction and learning (Atkinson, 2002; Clark & Mayer, 2016; Mayer et al., 2003; Mayer et al., 2018; Mayer & Chandler, 2001; Mayer & Moreno, 1998; Mayer & Pilegard, 2014; Moreno, 2007; Moreno & Mayer, 1999; Mousavi et al., 1995). There are few research studies have explored the simultaneous use of two multimedia principles, and these studies have shown mixed results (Cheon et al., 2014; Dousay, 2016; Hassanabadi et al., 2011; Singh et al., 2012; Stiller et al., 2009).

CHAPTER III

Methods

The purpose of this research was to study the influence of using different combinations of the modality and segmenting principles on gear instruction. The gear instruction aimed at teaching students to (a) identify the drive gear and driven gear from a gear system, (b) understand the rotation direction of gear systems, and (c) discover the relationship between the teeth and the rotation of gear systems. Four to five minutes long instructional videos were produced as instructional materials to teach this content. Students watched the instructional video, completed generative activities, and took a posttest. This study addressed these research questions:

1. Is there a statistically significant main effect of using the modality principle in electronic instruction on students' overall test scores on gear systems over not using modality?
    - 1.1. Is there a statistically significant main effect of using the modality principle in electronic instruction on students' recall test scores on gear systems over not using modality?
    - 1.2. Is there a statistically significant main effect of using the modality principle in electronic instruction on students' transfer test scores on gear systems over not using modality?
2. Is there a statistically significant main effect of using the segmenting principle in electronic instruction on students' overall test scores on gear systems over not using segmenting?

2.1. Is there a statistically significant main effect of using the segmenting principle in electronic instruction on students' recall test scores on gear systems over not using segmenting?

2.2. Is there a statistically significant main effect of using the segmenting principle in electronic instruction on students' transfer test scores on gear systems over not using segmenting?

3. Are there statistically significant interaction effects of using different combinations of modality and segmenting principles on students' learning?

3.1. Does using the segmenting principle alone improve overall learning versus using neither principle?

3.1.1. Does using the segmenting principle alone improve recall learning versus using neither principle?

3.1.2. Does using the segmenting principle alone improve transfer learning versus using neither principle?

3.2. Does using the modality principle alone improve overall learning versus using neither principle?

3.2.1. Does using the modality principle alone improve recall learning versus using neither principle?

3.2.2. Does using the modality principle alone improve transfer learning versus using neither principle?

3.3. Is there a difference between students' overall learning when taught with the modality principle alone versus the segmenting principle alone?

3.3.1. Is there a difference between students' recall learning when taught with the modality principle alone versus the segmenting principle alone?

3.3.2. Is there a difference between students' transfer learning when taught with the modality principle alone versus the segmenting principle alone?

3.4. Does using both the segmenting and modality principles together increase overall learning compared to segmenting alone?

3.4.1. Does using both the segmenting and modality principles together increase recall learning compared to segmenting alone?

3.4.2. Does using both the segmenting and modality principles together increase transfer learning compared to segmenting alone?

3.5. Does using the segmenting and modality principles together increase overall learning compared to modality alone?

3.5.1. Does using the segmenting and modality principles together increase recall learning compared to modality alone?

3.5.2. Does using the segmenting and modality principles together increase transfer learning compared to modality alone?

Participants

A minimum of 120 college students were the desired sample size for this research to meet the assumptions for the chosen statistic. These students were selected from the student body at a medium-sized university in the Intermountain West. Myers et al. (2013) stated that the larger the sample size, the more precisely it estimated population values and the greater the statistical power to detect a true effect of the exposure or intervention. These authors also pointed out the following advantages of a large sample size: it's beneficial for subgroup analysis, which can help to identify differences in treatment effects among different demographic or clinical subgroups; it also increases the generalizability of study findings to the target population; and it provides a greater margin of error and can help to address potential dropouts or loss of subjects over time (Myers et al., 2013). Thus, seeking 200 participants with 50 participants per group provided sufficient statistical power, reduced the risk of type II errors, and increased the generalizability of study findings.

Several criteria were determined to include or exclude participants for this study. First, because this research involved using the visual and auditory senses of the participants, students with significant visual or hearing impairments were excluded. Additionally, students with previous knowledge of the research instruction were excluded to reduce outliers in the sample data. If students with knowledge of research instruction were found to have participated, their data on research instruction were not used in the analysis.

Research Method

This study used a 2x2 factorial between-groups design. The independent variable was the variable to be manipulated and is assumed to directly affect the dependent variable (Myers et al., 2013). In this research, the modality and segmenting principles were the two independent variables, each with two levels, use, and non-use. The dependent variable was measured in the experiment and tested as dependent on the independent variables (Myers et al., 2013). In this research, the dependent variables were the learner's scores on the posttest for overall, transfer, and recall knowledge.

Participants were randomly assigned to one of four groups. The first group, the control group (C), received a multimedia lesson without either segmenting or modality principles applied in the instruction. Students in the C group watched a long video with written subtitles and completed generative activities after watching the video. The second group was the modality principle group (M). Mayer (2021) stated that the modality principle includes visual images with verbal narratives rather than using visual images with printed text in instruction. Students in the M group watched a long video with audio narration and did the generative activities after the video. The third group was the segmenting principle group (S). The segmenting principle consisted of presenting information in segments rather than as a continuous stream (Mayer, 2021). Students in the S group watched segmented videos with written subtitles and performed generative activities between each segment. The last group was the modality and segmenting principles group (MS). Students in the MS group watched segmented videos with audio narration and did the generative activities between each segment. More details of instruction treatment differences can be found in Table 1 below. Although these groups received different instructional methods, they were taught the same content. All participants took an identical posttest at the end of the treatments. After the test, all the participants' scores were collected and prepared for data analysis. All these studies were carried out in the lab. The participation process for the students involved consulting the key information form (see Appendix A) and signing the consent form (see Appendix B) before proceeding with the study.

Table 1

Instruction Treatment for Each Group

Treatment types	No Segmenting	Segmenting
No Modality	Treatment C (control) Single "long" video Text on screen (CC)	Treatment S (segmenting only) A number of "short" videos Text on screen (CC)
Modality	Treatment M (modality only) Single "long" video Audio narration	Treatment MS (modality and segmenting) A number of "short" videos Audio narration

Note. Different groups only received different instructional methods. All groups were taught the same content.

Treatment Design

The instruction in this research was designed following the ASSURE instructional development model. The ASSURE model focused on planning and implementing instructions that included technologies and allowed instructors to develop instructional plans for technology integration and media use (Smaldino et al., 2015). According to Smaldino et al. (2015), the steps of the ASSURE model are analyzing learners, stating objectives, selecting media and materials, utilizing media and materials, requiring learner participation, and evaluating and revising.

In the ASSURE model, analyzing learners means instructional designers should consider students' ages, genders, academic abilities, interests, prior skills, and learning styles (Smaldino et al., 2015). This information from students can help instructional designers know what students' strengths and weaknesses are. Smaldino et al. (2015) recommended that describing learners' characteristics allows teachers to align the learning methodologies and environment to a learner's strengths and needs. For this instruction, the researcher descriptively analyzed the students' age, ensuring they were not too young to understand the instruction. In addition, students' skills prior to this study were considered, ensuring that the students were both ready for instruction and not already experts in gear mechanics.

The second step of the ASSURE model focuses on assigning instructional objectives. Instructional designers should write objectives based on the knowledge or skills students need to master (Smaldino et al., 2015). The instructional objectives of this study were: identifying the drive gear and driven gear from a gear system, realizing the direction of rotation of gear systems, and understanding the mathematical relationship between the number of gear teeth and the number of rotations in gear systems. These instructional objectives were given to participants after they were placed into groups. Therefore, they knew what they would be taught and what to accomplish to show mastery of the content.

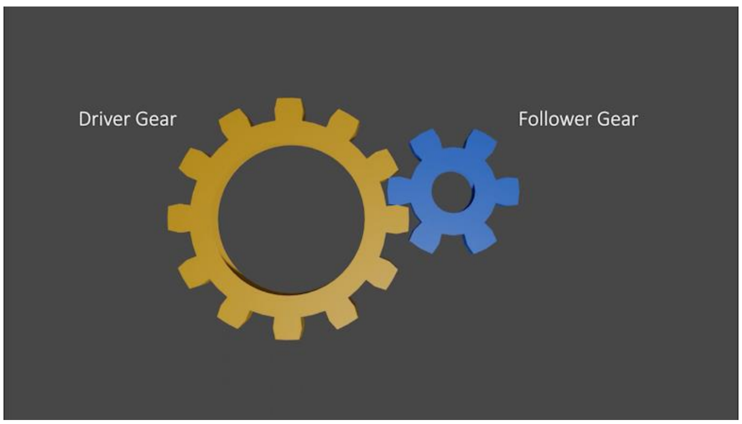
The following two steps of the ASSURE model are select media and materials and utilize the media and materials. Instructional designers aim to develop methods and select media and materials to help students achieve their objectives (Smaldino et al., 2015). The instructional media in this study were virtual 3D model gears. These 3D model gears could help students observe the operation of gear systems from different apparent angles on their computer screens (see Appendix C). The instructional media were designed and applied to the different groups according to the modality and segmenting principles. The groups using the modality principle included a video with audio narration. However, the groups not using the modality principle used a video with written subtitles. The subtitles exactly matched the spoken narration. The groups using the segmenting principle received a video presented in smaller segments with activities between each portion of the video. The groups not using the segmenting principle had a long continuous video with all activities after the end of the video (see Appendix D). Although the instructional media presented the content differently for the groups, the video content for all was identical; the only difference was in the order of the instructional elements. The instructional media allowed students to observe a 3D gear system. Students learned the components of a gear system and some characteristics, such as the gear names and changes in the directions of rotation. Then, the video provided a running gear system with some guiding questions. Students could learn about the relationship between the number of teeth and the number of rotations of gears.

The following two steps of the ASSURE model were selecting media and materials and utilizing the media and materials. Instructional designers aimed to develop methods and select media and materials to help students achieve their objectives (Smaldino et al., 2015). The instructional media in this study were virtual 3D model gears. These 3D model gears helped students observe the operation of gear systems from different apparent angles on their computer screen. All 3D models shown in the videos were made using Blender, a freeware 3D-modeling program. Gears with 4 to 24 teeth were made. Because there were differences in tooth size between different gear models, all gear models were expanded to a set of gear models with equivalent tooth sizes for the animation of different gear systems. After solving the tooth size problem of the gear models, the interoperation between these gear models needed to be calculated. If the rotation ratio of a gear system composed of two or more gear models was computed incorrectly, this gear system could still spin; however, this gear system caused the gear models to inter-penetrate when they were rotated. In order for a 3D modeled gear system to visually work like a physical gear system, the teeth of the gears in the gear system needed to be of the same size and the rotation ratio needed to be correct.

After completing the production and operation of the 3D gear models, the rest of the video content was designed. The first part of the video instruction introduced specific gear terminology used in the video. In this part, some words appeared in the video, and the purpose of these words was to mark and illustrate. Figure 1 shows a screenshot that has markers on which gear is the driver gear and which gear is the follower gear for students.

Figure 1

Screenshot of identify the driver gear and follower gear

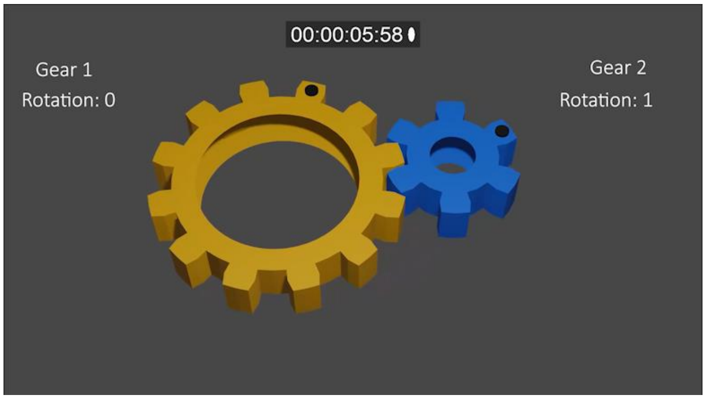


Note: Some explanatory words appear near the corresponding gears to help students understand the names of the different gears in this gear system.

After identifying the driver and follower gears, the rotation speed of each gear was explained. As shown in Figure 2, when a gear system is in operation, a timer will appear on the top of the screen, and the two ends of the screen will display the name of the corresponding gear as well as the number of rotations.

Figure 2

Screenshot of recognize the rotational speed of gears in a gear system

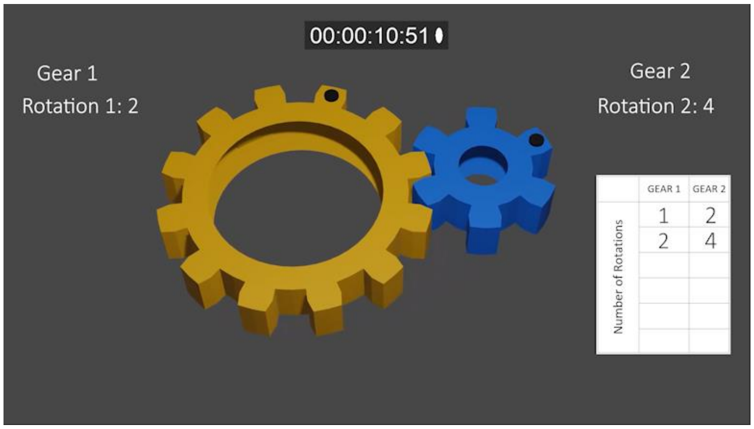


Note: The time on the timer and the number of rotations will change according to the operation of the gear system. Also, the black dots are used to show the rotations of each gear.

Finally, the relationship between the number of rotations of each gear and the number of teeth of each gear was explained and the formula was derived. After several rotations of the gear system, a table recording the number of rotations of each gear in the system appeared in the lower right corner of the video, as shown in Figure 3. This table was designed to help students observe the changes and the pattern of the number of rotations of the gear system. All of the information on the table was designed to help students better observe and understand the operation of the gear system. After showing a number of gear rotations, a formula was presented to help students better understand the relationship between the number of teeth and the number of rotations of each gear in the system, as shown in Figure 4. In general, the order of the content in the video was from simple to complex according to instructional objectives.

Figure 3

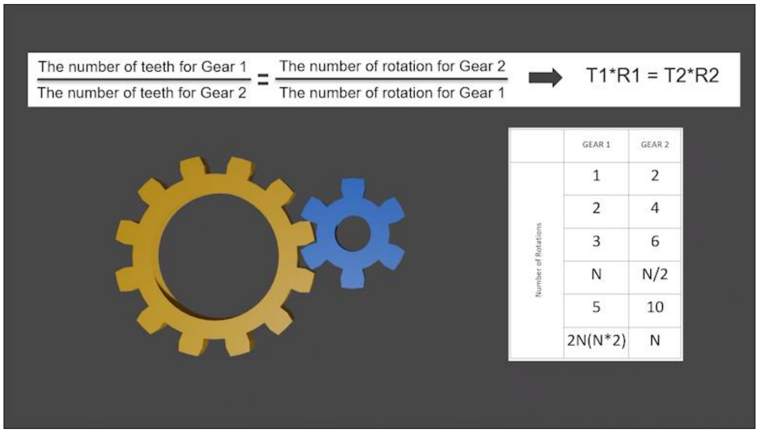
Screenshot showing the number of rotation of gears in a gear system



Note: The numbers in the table will change according to the rotation of the gear system.

Figure 4

Screenshot showing the number of rotation of gears and the formula

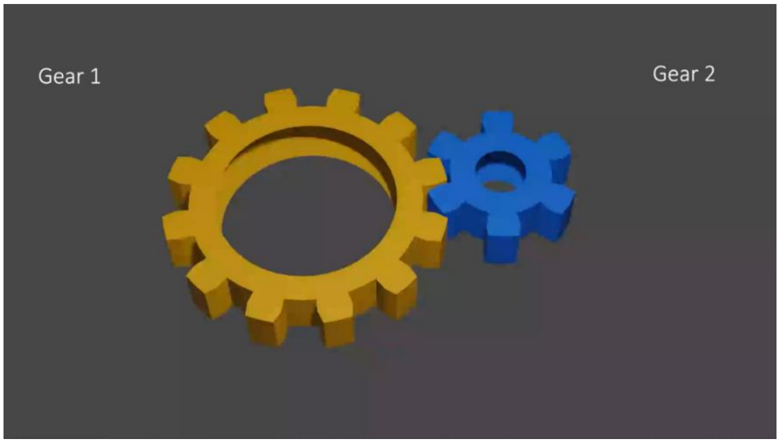


Note: Both table and formula are presented to help students understand the principles of the formula.

The instructional video was designed and applied to the different groups according to the modality and segmenting principles. As shown in Figure 5, the groups using the modality principle included a video with audio narration. However, the groups not using the modality principle used a video with written subtitles, as shown in Figure 6. All the subtitles exactly matched the spoken narration.

Figure 5

Examples of the video that application of the modality principle



Note: Videos like this will have audio but no subtitles.

Figure 6

Examples of the video that not application of the modality principle

Note: Videos like this will have subtitles but no audio.

The groups that used the segmenting principle received a video presented in smaller segments with activities between each portion of the video. The groups that did not use the segmenting principle had a long continuous video with all activities after the end of the video (see Appendix E). Although the instructional media presented the content differently for the groups, the video content for all was identical; the only difference was in the order of the instructional elements. The instructional media allowed students to observe a 3D gear system. Students learned the components of a gear system and some characteristics, such as the gear names and changes in the directions of rotation. Then, the video provided a running gear system with some guiding questions. Students could learn about the relationship between the number of teeth and the number of rotations of gears.

The fifth step of the ASSURE model requires instructional designers to encourage students to actively participate in the instruction (Smaldino et al., 2015). In this study, H5P activities were designed to assist and guide the learning process (see Appendix F). These activities helped students better learn and master the content. For example, a drag-and-drop activity supported students in selecting the correct gears to create a system according to the desired ratio of teeth to rotations. All students watched the instructional video and completed these generative activities to remain engaged. However, different groups did these activities at different points in the instruction. For groups with the segmenting principle, students performed activities after each segment. For the groups without the segmenting principle, the students did all activities sequentially after watching the long version of the video.

The last step of the ASSURE model is to evaluate and revise. Instructional designers should design an evaluation method to ensure that the instruction can be improved in the future (Smaldino et al., 2015). For this research, the formative assessment involved letting subject matter experts examine the content of the instruction before using them in the research. For the summative assessment, researchers compared the effectiveness of four different instructional methods after the research.

Instrument

The posttest was designed to test students' mastery of the content. The posttest consisted of a combination of transfer and recall questions in multiple-choice, true and false, and problem-solving formats (see Appendix G). The multiple-choice and true-and-false questions focused on recalling the properties and laws of gear systems. For example, the questions could have included having students identify the direction of rotation of a specific gear in a gear system. The problem-solving questions required students to calculate the number of teeth or rotations for systems. For example, knowing the number of teeth of two gears and the number of rotations of one gear provided students with information to calculate the number of rotations of the other gear.

All the questions on the posttest were based on the instructional objectives. As the content of the posttest involved simple machinery, the content validity evidence was collected after the posttest questions had been checked by subject-matter experts.

Data Collection

The posttest appeared immediately after students viewed and participated in the instruction. All students took the content knowledge posttest, which was a combination of recall and transfer questions in multiple-choice, true and false, and problem-solving formats. Students only needed to use the information from the instruction to select their answers since there were no short answer or essay questions on the posttest. Therefore, the items all had a single answer which was objectively scored as correct or incorrect. Each participant's posttest was graded to find their recall, transfer, and overall scores.

Data Analysis

After collecting the posttest scores, the researcher used SPSS to analyze the data using a 2x2 factorial MANOVA. A 2x2 factorial MANOVA is used to understand the effects of two independent variables and their interaction effects on multiple dependent variables (Myers et al., 2013). The modality and segmenting principles were the two independent variables, each with two levels, use and non-use. The dependent variables were the learner's performance on the posttest for recall, transfer, and overall scores. By using a 2x2 factorial MANOVA, the following main effects could be observed. The first main effect was the modality principle on each of the dependent variables. The researcher analyzed the impact of using the modality principle in instruction by comparing the mean of students' scores on the posttest from C and S groups to M and MS groups. The second main effect was the segmenting principle in instruction. This was analyzed by comparing the mean of students' scores on the posttest from the combined C and M groups to the combined S and MS groups. The interaction effects of M and S groups were also examined by the MANOVA. The interaction effect determined if there was a different impact of one of the independent variables based on the use or non-use of the other independent variable. According to the research design, the schedule for research was provided in Table 2.

Table 2

Research Timeline

Research Events	**Time Duration**
Data Collection	11 weeks
Data Analysis	1 week
Reporting Results	2 weeks

CHAPTER IV

Results

The purpose of this study was to test if using modality and segmenting principles simultaneously, or a single principle better managed intrinsic load for learners learning a new content. This study compared results of recall, transfer, and overall scores between four treatment groups, which are C, M, S, and MS.

This chapter will discuss the sample and descriptive statistics followed by the inferential statistics for each research question. The null and alternative hypotheses will also be shown for clarity.

Description of the Sample

Even though the researcher of this study actively advertised the study and recruited participants, the sample consisted of only 71 participants. This was short of the desired minimum samples of 120 discussed in Chapter III. There were several possible reasons that may have resulted in the study being able to recruit only this number of participants. First, the in-person study design asked participants to come to IMPROVE Lab for 20-25 minutes of their time and receive a $10 Amazon gift card as an incentive. Some people do not want to participate because they live far away from the lab, even they showed an interest in the subject of the study. A second possible reason is that the data collection began during the last three weeks of the spring semester and continued for seven weeks of the summer semester. During the last three weeks of the spring semester, most students on campus did not participate to the study because they may have been too busy to preparing for their finals. In the summer semester, most students were taking courses online, reducing the number of students on campus. For these reasons, this study only recruited 71 participants instead of 200 participants as planned.

All 71 participants were older adults; they were students or summer staff at the institution. None mechanical engineering students, who may have already been experts in the content. Also, the participants were not visually or audially disadvantaged, so each participant was able to make full use of the audio-visual elements of the multimedia treatments. All participants were either residents in the city where the university was located or visiting the university's location.

Descriptive Statistics

All 71 participants completed the posttest and were not found to be outliers. There was a total of 20 participants in the C group, 17 participants in the M group, 16 participants in the S group, and 18 participants in the MS group. Table 3 (below) shows the descriptive statistics of each treatment group for overall, recall, and transfer posttest scores. The posttest had a total of 12 questions, 6 recall questions and 6 transfer questions. Participants got one point for each correct response, so there are total of 12 points possible, 6 possible points for the recall questions and 6 possible points for the transfer questions.

Table 3

Dependent Variables Descriptive Statistics Disaggregated by the Independent Variables (N = 71)

	Control (no principle) (n=20)		Modality (only modality) (n=17)		Segmenting (only segmenting) (n=16)		Segmenting * Modality (two principles) (n=18)	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Overall	10.90	1.410	11.29	.772	11.44	.964	11.17	.707
Recall	5.50	.688	5.65	.606	5.75	.577	5.56	.511
Transfer	5.40	.940	5.65	.606	5.69	.479	5.61	.502

Note. Table 1 shows the means and standard deviations of the overall, recall, and transfer scores for each treatment group.

The control group had the largest number of people with 20 subjects, and the segmenting group had the smallest number of people with 16 participants. The mean value for all type of the scores were very similar for each group. For overall posttest scores, the segmenting group had the highest mean (11.44). The control group had the lowest mean (10.90). The control group also had the lowest recall mean (5.50) and transfer mean (5.40). In contrast, the segmenting group had the highest recall mean (5.75) and transfer mean (5.69). For highest standard deviation, the control group had 1.410 which means this treatment group had the highest variability.

Results for Research Question 1

The first research question examined the main effect of modality on overall posttest scores. To determine if there was a statistically significant difference in overall scores between the C and S groups and M and MS groups, a 2x2 Factorial MANOVA was calculated on overall posttest scores. All groups' variances were found to be statistically equivalent because no violation of the assumption of homogeneity of variance was found by the Levene's test. Research question 1 is shown below along with its null and alternative hypotheses.

1. Is there a statistically significant main effect of using the modality principle in electronic instruction on students' overall test scores on gear systems over not using modality?

   H_0: There is no statistically significant difference between overall posttest scores for the C and S groups and M and MS groups.

   H_1: There is a statistically significant difference between overall posttest scores for the C and S groups and M and MS groups.

The results of the 2x2 Factorial MANOVA showed no significant main effect for modality on the overall posttest scores [F (2, 67) =.064, p = .801]. These results showed the groups taught with modality principle achieved no differently than groups taught with no modality principle on the overall posttest scores. The most direct interpretation of this finding is that the overall posttest scores were not affected by the modality principle used in the treatments. It should be noted that the effect size was .001 which is a small effect according to (Pierce et al., 2004). Also, the observed power was .057. This implies that there was only a 5.7% chance of seeing an effect of size .001 as statistically significantly different.

Results for Research Question 1.1

Research question 1.1 asked if there was a statistically significant main effect of using the modality principle on students' recall test scores over not using modality.

1.1. Is there a statistically significant main effect of using the modality principle in electronic instruction on students' recall test scores on gear systems over not using modality?

H_0: There is no statistically significant difference between recall posttest scores for the C and S groups and M and MS groups.

H_1: There is a statistically significant difference between recall posttest scores for the C and S groups and M and MS groups.

The results showed no significant main effect on recall scores for modality use [F (2, 67) = .027, p = .869]. These results revealed groups taught with or without the modality principle scored statistically equivalently on the recall posttest scores. This finding implies that the recall posttest scores were not affected by the modality principle used in the treatments. Please note that the effect size, which was found to be .000, is considered small according to (Pierce et al., 2004). Here, the .000 effect size did not mean there is no effect, it means the effect size is smaller than .0005 and rounded down to .000 (Myers et al., 2010). Additionally, the observed power was .053, indicating a mere 5.3% probability of observing a statistically significant difference for an effect size of .000.

Results for Research Question 1.2

The research question 1.2 asked if there was a statistically significant main effect of using the modality principle on students' transfer test scores over not using modality.

1.2. Is there a statistically significant main effect of using the modality principle in electronic instruction on students' transfer test scores on gear systems over not using modality?

H_0: There is no statistically significant difference between transfer posttest scores for the C and S groups and M and MS groups.

H_1: There is a statistically significant difference between transfer posttest scores for the C and S groups and M and MS groups.

This study found no significant main effect on transfer scores due to modality [F (2, 67) = .283, p = .597]. These results imply that groups taught with modality and no modality had no differences on the transfer posttest scores. However, it should be noted that the effect size observed in this study was .004, indicating a small effect size (Pierce et al., 2004). Furthermore, the observed power was .082, suggesting that there was only an 8.2% probability of detecting a statistically significant difference for an effect size of .004.

Results for Research Question 2

The second major research question examined whether there was a statistically significant main effect of using the segmenting principle on students' overall posttest scores. According to the Levene's test, there was no violation of the assumption of homogeneity of variance, indicating that all groups' variances were statistically equivalent. Therefore, it was appropriate to use a 2x2 Factorial MANOVA to determine if there was a statistically significant difference in overall scores between the C and S groups and M and MS groups. The following research question generated the null and alternative hypotheses below.

2. Is there a statistically significant main effect of using the segmenting principle in electronic instruction on students' overall test scores on gear systems over not using segmenting?

   H_0: There is no statistically significant difference between overall posttest scores for the C and M groups and S and MS groups.

   H_1: There is a statistically significant difference between overall posttest scores for the C and M groups and S and MS groups.

The results of the MANOVA showed no significant main effect for overall posttest scores for segmenting [F (2, 67) = .712, p = .402]. These results showed the groups taught with segmenting scored no differently than groups taught with no segmenting on the overall posttest scores. The primary interpretation of this finding suggests that the utilization of the segmenting principle in the treatments did not have a substantial impact on the overall posttest scores. Importantly, the effect size of .011, as per Pierce et al. (2004), indicates a small effect. The observed power of .132 implies a mere 13.2% probability of observing a statistically significant difference for an effect size of .011.

Results for Research Question 2.1

Research question 2.1 asked is there a statistically significant main effect of using the segmenting principle on students' recall posttest scores over not using segmenting.

2.1. Is there a statistically significant main effect of using the segmenting principle in electronic instruction on students' recall test scores on gear systems over not using segmenting?

H_0: There is no statistically significant difference between recall posttest scores for the C and M groups and S and MS groups.

H_1: There is a statistically significant difference between recall posttest scores for the C and M groups and S and MS groups.

For recall posttest scores, the results showed no significant main effect for segmenting [F (2, 67) = .305, p = .583]. This means the groups taught with segmenting scored no differently than groups taught with no segmenting on the recall posttest scores. These results show that the recall posttest scores were not affected by the segmenting principle used in the treatments. Additionally, the effect size was .005 which is a small effect size (Pierce et al., 2004). The observed power was .085. This means that there was only an 8.5% chance of seeing an effect of size .005 as statistically significantly different.

Results for Research Question 2.2

Research question 2.2 asked is there a statistically significant main effect of using the segmenting principle on students' transfer posttest scores over not using segmenting.

2.2. Is there a statistically significant main effect of using the segmenting principle in electronic instruction on students' transfer test scores on gear systems over not using segmenting?

H_0: There is no statistically significant difference between transfer posttest scores for the C and M groups and S and MS groups.

H_1: There is a statistically significant difference between transfer posttest scores for the C and M groups and S and MS groups.

The results of the research question 2.2 showed no significant main effect for transfer posttest scores for using segmenting [F (2, 67) = .615, p = .436]. These results showed the groups taught with segmenting scored no differently than groups taught with no segmenting on the transfer posttest scores. This finding means that the transfer scores were not affected by the segmenting principle used in the treatments. However, the effect size observed in this study was determined to be .009, indicating a small effect size (Pierce et al., 2004). Moreover, the observed power of .121 suggests that there was merely a 12.1% of detecting a statistically significant difference for an effect size of .009.

Results for Research Question 3

A number of comparisons were used to address the difference parts of research question 3. This was done in order to compare individual treatment groups to other treatments groups of interest. Firstly, comparisons were conducted between group C and both group M and group S to examine the impact of modality or segmenting alone on learning. Secondly, a comparison was made between group M and group S to ascertain which principle, if any, was more effective in enhancing students' learning. Finally, two comparisons were made between to examine if the M or S groups were had different results than the MS group. These comparisons would determine if the utilization of both principles together yielded superior results compared to either principle alone. The subparts of the third research question sought to determine if there were any interaction effects of using different combinations of modality and segmenting principles on learning.

3. Are there statistically significant interaction effects of using different combinations of modality and segmenting principles on students' learning?

Results of the 2x2 Factorial MANOVA found that there were no statistically significant differences among the four groups (control, modality, segmenting, and segmenting & modality) on the overall [F (1, 67) = 1.872, p = .176], recall [F (1, 67) = 1.416, p = .238], and transfer [F (1, 67) = 1.016, p = .317] posttest scores. Therefore, this study found no evidence that any of the treatments affected overall, recall, and transfer test scores. However, the effect size of the overall was .027 and the power was .271. The recall effect size was .021 and the power was .216. The effect size of the transfer was .015 and the power was .169. All these effects size of overall, recall, and transfer were considered a small effect size (Pierce et al., 2004). Also, they all had low observed power implying a low chance of seeing an effect of these small size as statistically significant. More results are presented in the sub-questions of research question 3 below.

Results for Research Question 3.1

Research question 3.1 asked if using the segmenting principle alone improves overall learning better than using neither principle. To determine if there was a statistically significant difference in overall scores, a set of planned contrasts were computed on posttest scores. For research question 3.1, the planned contrasts reported below compared only the C and S treatment groups.

3.1. Does using the segmenting principle alone improve overall learning versus using neither principle?

H_0: There is no statistically significant difference between overall posttest scores for the C and S groups.

H_1: There is a statistically significant difference between overall posttest scores for the C and S groups.

The planned comparison that examined for differences between the control and segmenting alone groups' overall scores found no significant differences ($t = 1.570$, $df = 67$, $p = .121$). Therefore, the planned comparison agreed with the overall MANOVA that there were no differences between the group only using segmenting and the group using neither principle on the overall posttest scores. The most direct interpretation of this finding is that the overall posttest scores were not affected by the segmenting principle compared to the control group. It should be noted that the effect size was .011 in overall MANOVA, which is a small effect according to Pierce et al., (2004). Also, the observed power was .132. This implies that there was only a 13.2% chance of seeing an effect of this size as statistically significantly different.

Results for Research Question 3.1.1. The research question 3.1.1 asked if using the segmenting principle alone improves recall learning better than using neither principle.

3.1.1. Does using the segmenting principle alone improve recall learning versus using neither principle?

H_0: There is no statistically significant difference between recall posttest scores for the C and S groups.

H_1: There is a statistically significant difference between recall posttest scores for the C and S groups.

For recall learning, the results showed no statistically significant difference between C and S groups for recall posttest scores (t = 1.237, df = 67, p = .220). These results showed the group only using segmenting principle no differently than the group using neither principle on the recall posttest scores. These finding state that applying the segmenting principle did not improve recall scores compared to the control group. However, the recall MANOVA revealed an effect size of .005, which is considered a small effect (Pierce et al., 2004). Additionally, the observed power was .085, suggesting a mere 8.5% probability of detecting a statistically significant difference for an effect of this effect size.

Results for Research Question 3.1.2. Research question 3.1.2 asked if using the segmenting principle alone improves transfer learning better than using neither principle.

3.1.2. Does using the segmenting principle alone improve transfer learning versus using neither principle?

H_0: There is no statistically significant difference between transfer posttest scores for the C and S groups.

H_1: There is a statistically significant difference between transfer posttest scores for the C and S groups.

The results showed no statistically significant difference between C and S groups for transfer posttest scores (t = 1.273, df = 67, p = .208). These results indicated that the group using the segmenting principle did not differ from the group that did not use any principle in terms of the transfer posttest scores. Therefore, the segmenting principle employed in the treatments did not have an impact on transfer scores compared to the control group. For the transfer scores examined by the MANOVA, the effect size was .009, signifying a small effect size (Pierce et al., 2004). Furthermore, the observed power was .121, implying that there was only 12.1% of observing a statistically significant difference for an effect size of .009.

Results for Research Question 3.2

Research question 3.2 asked if using the modality principle alone improves overall learning better than using neither principle. To determine if there was a statistically significant difference in overall posttest scores, a set of planned contrasts were computed on posttest scores.

3.2. Does using the modality principle alone improve overall learning versus using neither principle?

H_0: There is no statistically significant difference between overall posttest scores for the C and M groups.

H_1: There is a statistically significant difference between overall posttest scores for the C and M groups.

There was no statistically significant difference between C and M groups for overall posttest scores (t = 1.171, df = 67, p = .246). These results showed the group only using modality principle no differently than the group using neither principle on the overall posttest scores. These findings suggest that the utilization of the modality principle in the treatments did not have an impact on the overall scores compared to the control group. Importantly, the effect size was .001 in overall MANOVA, indicating a small effect size (Pierce et al., 2004). Additionally, the observed power was .057, implying a 5.7% probability of observing a statistically significant difference for an effect size of .001.

Results for Research Question 3.2.1. Research question 3.2.1 asked if using the modality principle alone improves recall learning better than using neither principle.

3.2.1. Does using the modality principle alone improve recall learning versus using neither principle?

H_0: There is no statistically significant difference between recall posttest scores for the C and M groups.

H_1: There is a statistically significant difference between recall posttest scores for the C and M groups.

For recall learning, the results showed no statistically significant difference between C and M groups for recall posttest scores (t = .740, df = 67, p = .462). These results showed the group only using modality principle no differently than the group using neither principle on the recall posttest scores. This finding meant that the recall posttest scores were not affected by the modality principle used in the treatments compared to the control group. In the recall analysis portion of the MANOVA, the effect size was .000 which is a small effect according to (Pierce et al., 2004). The .000 effect size here did not mean there was no effect, it means the effect size is smaller than .0005 and rounded down to .000 (Myers et al., 2013). Also, the observed power was .053. This implies that there was only a 5.3% chance of seeing an effect of this size as statistically significantly different.

Results for Research Question 3.2.2. Research question 3.2.2 asked if using the modality principle alone improves transfer learning better than using neither principle.

3.2.2. Does using the modality principle alone improve transfer learning versus using neither principle?

H_0: There is no statistically significant difference between transfer posttest scores for the C and M groups.

H_1: There is a statistically significant difference between transfer posttest scores for the C and M groups.

The results showed no statistically significant difference between C and M groups for transfer posttest scores (t = 1.112, df = 67, p = .270). These results showed the group only using modality principle no differently than the group using neither principle on the transfer posttest scores. The most direct interpretation of this finding is that the transfer posttest scores were not affected by the modality principle used in the treatments compared to the control group. The effect size was .004 in transfer MANOVA which is a small effect according to Pierce et al., (2004). Also, the observed power was .082. This implies that there was only an 8.2% chance of seeing an effect of size .004 as statistically significantly different.

Results for Research Question 3.3

Research question 3.3 asked if there is a difference between students' overall learning when taught with the modality principle or the segmenting principle. The Levene's test, indicated no violation of the assumption of homogeneity of variance, showing that M and S groups ' variances were statistically equivalent. To determine if there was a statistically significant difference in overall scores between the M and S groups, a set of planned contrasts were computed on posttest scores.

3.3. Is there a difference between students' overall learning when taught with the modality principle alone versus the segmenting principle alone?

H_0: There is no statistically significant difference between overall posttest scores for the M and S groups.

H_1: There is a statistically significant difference between overall posttest scores for the M and S groups.

For overall learning, the results showed no significant difference between modality principle and segmenting principle for overall posttest scores (t = .403, df = 67, p = .688). These results indicated that there were no significant differences in the overall posttest scores between the group only utilizing the modality principle and the group only utilizing the segmenting principle. This finding suggests that the overall posttest scores were not affected by the specific use of either the modality principle alone or the segmenting principle alone in the treatments. Importantly, the effect size was .027 in overall MANOVA, which represents a small effect size according to (Pierce et al., 2004). Furthermore, the observed power was .271, indicating that there was only a 27.1% of observing a statistically significant difference for an effect size of .027.

Results for Research Question 3.3.1. Research question 3.3.1 asked if there is a difference between students' recall learning when taught with the modality principle or the segmenting principle.

3.3.1. Is there a difference between students' recall learning when taught with the modality principle alone versus the segmenting principle alone?

H_0: There is no statistically significant difference between recall posttest scores for the M and S groups.

H_1: There is a statistically significant difference between recall posttest scores for the M and S groups.

For recall learning, the results showed no significant difference between modality principle and segmenting principle for recall posttest scores (t = .490, df = 67, p = .625). These results showed the group only using the modality principle no differently than the group only using the segmenting principle on the recall posttest scores. This finding means that the recall posttest scores were not affected by using the modality principle alone or the segmenting principle alone in the treatments. It should be noted that the effect size was .021 in recall MANOVA which is a small effect according to (Pierce et al., 2004). Also, the observed power was .216. This implies that there was only a 21.6% chance of seeing an effect of size .021 as statistically significantly different.

Results for Research Question 3.3.2. Research question 3.3.2 asked if there is a difference between students' transfer learning when taught with the modality principle or the segmenting principle.

3.3.2. Is there a difference between students' transfer learning when taught with the modality principle alone versus the segmenting principle alone?

H_0: There is no statistically significant difference between transfer posttest scores for the M and S groups.

H_1: There is a statistically significant difference between transfer posttest scores for the M and S groups.

For transfer learning, the results showed no significant difference between modality principle and segmenting principle for transfer posttest scores (t = .172, df = 67, p = .864). The findings revealed that the group using only the modality principle did not differ significantly from the group using only the segmenting principle in terms of transfer posttest scores. This suggests that the transfer scores were unaffected by whether participants were exposed to the modality principle or the segmenting principle in the treatments. The effect size was .015 in transfer MANOVA, indicating a small effect size as per Pierce et al. (2004). Moreover, the observed power was .169, implying a 16.9% probability of observing a statistically significant difference for this effect size.

Results for Research Question 3.4

Research question 3.4 asked if using both the segmenting and modality principles together increases overall learning compared to segmenting alone. All groups' variances were found to be statistically equivalent because no violation of the assumption of homogeneity of variance was found by the Levene's test. To determine if there was a statistically significant difference in overall scores between the S and MS groups, a set of planned contrasts were computed on posttest scores.

3.4. Does using both the segmenting and modality principles together increase overall learning compared to segmenting alone?

H_0: There is no statistically significant difference between overall posttest scores for the MS and S groups.

H_1: There is a statistically significant difference between overall posttest scores for the MS and S groups.

The results showed no significant difference between S group and MS group on the overall posttest scores (t = -.772, df = 67, p = .443). These results showed the group using segmenting and modality principles together performed no differently than the group only using the segmenting principle on the overall posttest scores. This finding means that the overall posttest scores were not affected by using segmenting and modality principles together compared to segmenting alone in the treatments. The effect size in overall MANOVA was .027 which is a small effect according to Pierce et al., (2004). Also, the observed power was .271. This implies that there was only a 27.1% chance of seeing an effect of size .027 as statistically significantly different.

Results for Research Question 3.4.1. Research question 3.4.1 asked if using both the segmenting and modality principles together increases recall posttest scores compared to segmenting alone.

3.4.1. Does using both the segmenting and modality principles together increase recall learning compared to segmenting alone?

H_0: There is no statistically significant difference between recall posttest scores for the MS and S groups.

H_1: There is a statistically significant difference between recall posttest scores for the MS and S groups.

There was no significant difference observed between the S group and MS group in terms of recall posttest scores (t = -.939, df = 67, p = .351). These findings indicate that the group utilizing both segmenting and modality principles did not differ significantly from the group utilizing only the segmenting principle in terms of the recall posttest scores. Consequently, the utilization of both principles together did not have an impact on the recall scores. For recall, the effect size was .021, indicating a small effect size (Pierce et al., 2004). Additionally, the observed power was .216, suggesting a 21.6% probability of observing a statistically significant difference for an effect size of .021.

Results for Research Question 3.4.2. Research question 3.4.2 asked if using both the segmenting and modality principles together increases transfer posttest scores compared to segmenting alone.

3.4.2. Does using both the segmenting and modality principles together increase transfer learning compared to segmenting alone?

H_0: There is no statistically significant difference between transfer posttest scores for the MS and S groups.

H_1: There is a statistically significant difference between transfer posttest scores for the MS and S groups.

The results showed no significant difference between S group and MS group for transfer posttest scores (t = -.330, df = 67, p = .742). These results showed the group using segmenting and modality principles together no differently than the group only using the segmenting principle on the transfer posttest scores. This finding means that the transfer posttest scores were not affected by using segmenting and modality principles together in the treatments. Please noted that the effect size was .015 in transfer MANOVA which is a small effect according to (Pierce et al., 2004). Also, the observed power was .169. This implies that there was only a 16.9% chance of seeing an effect of size .015 as statistically significantly different.

Results for Research Question 3.5

Research question 3.5 asked if using both the segmenting and modality principles together increases overall learning compared to modality alone. All groups' variances were found to be statistically equivalent because no violation of the assumption of homogeneity of variance was found by the Levene's test. To determine if there was a statistically significant difference in overall scores between the M and MS groups, a set of planned contrasts were computed on posttest scores.

3.5. Does using the segmenting and modality principles together increase overall learning compared to modality alone?

H_0: There is no statistically significant difference between overall posttest scores for the MS and M groups.

H_1: There is a statistically significant difference between overall posttest scores for the MS and M groups.

The results showed no significant difference between MS group and M group on the overall posttest scores (t = -.369, df = 67, p = .713). These results showed the group using segmenting and modality principles together no differently than the group only using the modality principle for overall posttest scores. This finding meant that the overall posttest scores were not affected by using segmenting and modality principles together in the treatments. However, the effect size was .027 in overall MANOVA which is a small effect according to (Pierce et al., 2004). Also, the observed power was .271. This implies that there was only a 27.1% chance of seeing an effect of size .027 as statistically significantly different.

Results for Research Question 3.5.1. Research question 3.5.1 asked if using both the segmenting and modality principles together increases recall learning compared to modality alone.

3.5.1. Does using the segmenting and modality principles together increase recall learning compared to modality alone?

H_0: There is no statistically significant difference between recall posttest scores for the MS and M groups.

H_1: There is a statistically significant difference between recall posttest scores for the MS and M groups.

The results showed no significant difference between MS group and M group for recall posttest scores (t = -.449, df = 67, p = .655). These results showed the group using segmenting and modality principles together no differently than the group only using the modality principle on the recall posttest scores. The most direct interpretation of this finding is that the recall posttest scores were not affected by using segmenting and modality principles together in the treatments. However, the effect size was .021 in recall MANOVA, and it is a small effect according to (Pierce et al., 2004). Also, the observed power was .216. This implies that there was only a 21.6% chance of seeing an effect of size .021 as statistically significantly different.

Results for Research Question 3.5.2. Research question 3.5.2 asked if using both the segmenting and modality principles together increases transfer learning compared to modality alone.

3.5.2. Does using the segmenting and modality principles together increase transfer learning compared to modality alone?

H_0: There is no statistically significant difference between transfer posttest scores for the MS and M groups.

H_1: There is a statistically significant difference between transfer posttest scores for the MS and M groups.

The results of the 2x2 Factorial MANOVA showed no significant difference between MS group and M group for transfer posttest scores (t = -.158, df = 67, p = .875). These results showed the group using segmenting and modality principles together no differently than the group only using the modality principle for transfer posttest scores. This meant that the transfer posttest scores were not affected by using segmenting and modality principles together in the treatments. In transfer MANOVA, the effect size was .015 which is a small effect according to (Pierce et al., 2004). Also, the observed power was .169. This implies that there was only a 16.9% chance of seeing an effect of size .015 as statistically significantly different.

Summary of the Results

This experimental study analyzed the main and interaction effects of different combinations of modality and segmenting to determine if there was no statistical significance between C, M, S, and MS groups on overall, recall, and transfer posttest scores. This experiment was conducted using a short web-based lesson about two gear system for students at a medium-sized university in the intermountain west. With an alpha level of 0.05, there were no significant main effects for modality or segmenting for overall, recall, or transfer posttest scores. There were also no interaction effects of using different combinations of modality and segmenting principles on learning.

CHAPTER V

Conclusion

This study was conducted to determine if different combinations of modality and segmenting principles influenced learners' overall, recall, and transfer posttest scores. As part of the study, the researcher developed four treatments that taught an overview of the two-gear system. The four treatments groups included no principle (C); modality principle (M); segmenting principle (S); and modality and segmenting (MS). Learners were randomly assigned to one of the four treatment groups. See Chapter III for a detailed description of each treatment and the methods used in this study.

The same instructional content and materials were provided to all groups, but the way of content delivery differed across the four treatment groups. The study incorporated generative activities targeting recall and transfer, which were strategically embedded within the instructional lesson at varying intervals. The sequencing of these activities was contingent upon the instructional approaches adopted by each group. Specifically, the activities were administered subsequent to the instructional video for the C and M groups. The activities were broken into parts and interspersed among the shorter video segments for the groups that had segmenting, S and MS.

At the end of the treatment, participants were instructed to respond to a standardized posttest comprising six recall and six transfer questions. The scope of this study focused solely on the analysis of posttest data, with no utilization of a pretest or any alternative form of preassessment. This was an acceptable decision since the participants were randomly assigned to treatment groups.

Discussion of Experimental Results

The discussion and recommendations for each result have been organized by research questions below. Recommendations for both practice and research will be addressed.

Research Question 1

Research question 1 and two following sup-questions examined the main effect of modality on overall, recall, and transfer posttest scores.

1. Is there a statistically significant main effect of using the modality principle in electronic instruction on students' overall test scores on gear systems over not using modality?
   1.1. Is there a statistically significant main effect of using the modality principle in electronic instruction on students' recall test scores on gear systems over not using modality?
   1.2. Is there a statistically significant main effect of using the modality principle in electronic instruction on students' transfer test scores on gear systems over not using modality?

As mentioned in Chapter IV, the overall, recall, and transfer scores did not show any statistically significant main effect for modality when comparing the C and S groups to the M and MS groups. The most direct interpretation of this finding was that the overall, recall, and transfer posttest scores were not affected by the modality principle used in the treatments.

These findings suggested that using the modality principle in this instruction did not improve tests scores in any of the treatments tested in this study. This may indicate, with further confirmation by other research, that the intrinsic load was low enough that the use of modality was not necessary to learn the content well. This finding agrees with only three previous research studies (McNeill et al., 2009; Oberfoell & Correia, 2016; Tabbers et al., 2004).

There were some similarities between these three studies and the current study in terms of research methods. McNeill et al. (2009) conducted their study with only 56 participants, dividing them into three groups, with an average of 19 participants in each group. The sample size was as small as in the present study. Oberfoell and Correia (2016) also acknowledged the small sample size in their study, which consisted of 79 participants. These authors also found the captioning of their treatment to be too short and simple to detect the modality effect from another group. In the study by Tabbers et al. (2004), there was a sufficient sample size of 111 participants, but like this study, the test was administered immediately after the lesson.

In addition to the above three studies, the result of this research question was in contrast to most of the previous research on using modality principles in different studies (AbuSaada et al., 2013; Aldalalah et al., 2010; Dubois & Vial, 2000; Harskamp et al., 2007; Moreno & Mayer, 1999; Moreno et al., 2001; Tindall-Ford et al., 1997). There were several possible reasons in this study that could have contributed to these results, which differed from the majority of previous research.

The sample size of this study was 71 participants. The C group consisted of a total of 20 participants, while the M group consisted of 17 participants, S group consisted of 16 participants, MS group consisted of 18 participants. Despite the similarity in the number of participants in these four groups, the sample size was still considerably smaller than originally planned (50 participants per group). The reduced sample size in this study limited the statistical power to detect significant differences among the four groups, making it highly likely to yield findings of no significant differences.

Another reason for these results might be attributed to the brevity of the treatment in this study. The treatment consisted of a relatively short-duration of instructional content, lasting approximately 20 to 30 minutes. This included the presentation of instructional videos, either in the form of a single video (less than six minutes) or four shorter videos (totaling less than six minutes), along with eight activities and a 12-question posttest. The instructional videos primarily focused on topics such as the direction and speed of gear rotation, as well as the ratios of teeth and rotation of gear systems. In terms of the activities, they predominantly involved learners recalling specific knowledge points and applying that knowledge to example gears systems (near transfer). The brevity of the instruction may not have allowed the benefits of segmenting and modality that were found in prior studies to develop fully. This may explain the small effect sizes and lack of significant differences. Perhaps, over a longer lesson, the benefits of the multimedia principles may have accumulated to the point of reaching statistical significance.

Upon observation, the researchers noted that participants were able to complete all the instructional content within 20 minutes or less. For this reason, there might be some ceiling effects in this study. Ceiling effects occur when many participants in a study or the data points in a dataset reach the highest possible score or value on a particular measurement or assessment (Maxwell et al., 2017). It is important to consider that the majority of participants in the study were adults, and the nature of the videos and activities, which primarily involved recall-based and near-transfer tasks, might have been relatively straightforward for them. Consequently, many participants were able to achieve high scores on the posttest, regardless of the group to which they were assigned. This would reduce the apparent effects of the different treatments, reducing the possibility of find significant differences between groups.

It is possible that the instrument used in this study lacked enough difficult items to differentiate between medium and high levels of understanding in the participants. The posttest consisted of a total of 12 questions, with 6 focusing on recall and 6 on transfer. As previously mentioned, the recall questions may have been relatively simple for adult participants, and they accounted for half of the test questions. The remaining transfer questions may not have posed significant challenges to the participants either.

Additionally, the posttest was administered immediately after the lesson and activities, participants may have still retained some short-term memory of the recently learned material. The participants of non-segment groups were doing all the activities and receiving feedback immediately prior to the posttest. Even the groups with activities in the segmenting breaks had some of those important difficult activities and feedback immediately prior to the posttest. There could have been some carryover of participants' short-term memory from the activities and feedback during the posttest.

It is also a possibility that the instruction treatments provided in this study were highly effective. This high level of effectiveness could have facilitated participants' learning and retention of the knowledge, regardless of the group to which they were assigned. As a result, participants were able to perform well on most of the posttest questions. Again, this may have obscured any potential statistically significant differences between treatment groups.

It is possible that participants had pre-existing knowledge about gear systems that they were not aware of. The lesson in this study focused on gear systems in simple machines, a topic typically taught in the fifth grade in many elementary schools. Moreover, gears are commonly encountered in real-life applications. Therefore, participants may have already possessed a good understanding of gear characteristics, or the content of this instruction may have triggered the activation of participants' pre-existing knowledge about gears.

Recommendations for Future Practice. Previous research has demonstrated evidence of the effectiveness of modality (AbuSaada et al., 2013; Aldalalah et al., 2010; Dubois & Vial, 2000; Harskamp et al., 2007; Moreno & Mayer, 1999; Moreno et al., 2001; Tindall-Ford et al., 1997). However, it was found that using the modality principle may not be necessary in a single, short lesson (Mayer, 2021). It will be necessary to confirm this study's result by future research before such a recommendation could be made with confidence.

Real-world resource constraints, such as time and budget limitations, often require instructional designers to make trade-offs. If this study's results are confirmed, then designers and educators may choose not to employ any instructional principles, thereby reducing the design and development time. Based on the findings of this research question, it was concluded that the use of the modality principle did not yield significant learning benefits. Consequently, instructional designers and educators may opt to save resources, time, and money by not incorporating specific principles from this study into their courses.

Recommendations for Future Research. The findings from research question 1 needed to be confirmed by a follow-up study with a larger number of participants. Conducting such a study would have helped in determining whether the results of this study were a false negative or a valuable addition to the knowledge base for instructional designers.

The instructional topic chosen for this study might have been too simple to adequately assess the findings for complex content. Future research could use a different or more complex topic for the treatments and replicated the study to determine if it yielded different overall, recall, and transfer results. It is possible that the effectiveness of the modality principle may vary depending on the content area or difficulty levels. Further research is required to evaluate if different combinations have varying impacts on posttest scores across a range of content areas.

Future instruments could ask for more challenging test items that could help differentiate between medium and high levels of understanding in the participants. In subsequent studies involving adult participants, they could be asked to apply their knowledge and transfer it in the test, rather than solely recalling information or solving near transfer problems. The number of test questions could be increased, and a broader range of instructional objectives covered, resulting in a more effective instrument for assessing participants' mastery of the taught content.

In this study, the posttest was administered immediately after the treatment and the activities and feedback. This design solely focused on immediate learning. Hence, future research should examine delayed learning, which may yield different results. In delayed transfer, learners would have had more time to assimilate and comprehend the knowledge, and they might have developed new insights. The modality principle might have an impact on delayed transfer. Evaluating delayed transfer would have allowed learners more time to fully develop new knowledge and process the information provided in the instruction. The results could reveal that the modality principle is more effective for promoting delayed transfer by delaying the posttest for some period of time. The possibility that some knowledge might still be in participants' short-term memory would be eliminated in this scenario.

In future studies, a one-on-one, qualitative interviews could be conducted after the posttest. The primary purpose of these interviews would be to gather information on the reasons behind the participants' responses. Conducting such interviews could provide valuable insights for researchers, helping them determine whether participants have effectively mastered the course content or if their test responses were based on incorrect understanding or mere guessing. Furthermore, these interviews could also assess the effectiveness of the instructional methods employed in the study.

Research Question 2

Research question 2 and its subsequent sub-questions investigated the primary influence of segmenting on the scores of overall, recall, and transfer in the posttest.

2. Is there a statistically significant main effect of using the segmenting principle in electronic instruction on students' overall test scores on gear systems over not using segmenting?

    2.1. Is there a statistically significant main effect of using the segmenting principle in electronic instruction on students' recall test scores on gear systems over not using segmenting?

    2.2. Is there a statistically significant main effect of using the segmenting principle in electronic instruction on students' transfer test scores on gear systems over not using segmenting?

There was not any statistically significant main effect for segmenting when comparing the C and M groups to the S and MS groups on overall, recall, and transfer posttest scores. This finding meant that the overall, recall, and transfer posttest scores were not affected by the segmenting principle used in the treatments.

These findings suggest that the use of segmenting principles in instruction did not produce better learning. This conclusion challenges the majority of previous research on the use of segmenting principles in various studies (Ayres, 2006; Boucheix & Schneider, 2009; Chung et al., 2015; Hasler et al., 2007; Hassanabadi et al., 2011; Lusk et al., 2009; Mayer et al., 2003; Mayer et al., 2018; Mayer & Chandler, 2001; Mayer & Pilegard, 2014; Moreno, 2007; Spanjers et al., 2011; Stiller et al., 2009). Several possible reasons in this study may have contributed to these results, which differed from the majority of previous research.

As mentioned previously, the present study had limitations including a small sample size, brief treatment, and the presence of ceiling effects. The observed ceiling effects may be attributed to factors such as the simplicity test items of the instrument, the instrument was given immediately after the instruction, the effectiveness of the instructional intervention, and participants' potential pre-existing knowledge. These factors provide potential explanations for the absence of a significant segmenting effect in this study.

Additionally, the brevity of the instruction in this study may have contributed to the ineffectiveness of segmenting. As noted by Mayer (2021), segmenting is most effective when the instructional material is complex and contains a sufficient amount of information to potentially induce cognitive overload. Mayer also highlights that cognitive overload occurs when the capacity of short-term memory is exceeded by the influx of additional material. It is possible that the instruction in this study did not fulfill these conditions.

Recommendations for Future Practice. In previous research, segmenting has been shown to be effective in raising test scores (Ayres, 2006; Boucheix & Schneider, 2009; Chung et al., 2015; Hasler et al., 2007; Hassanabadi et al., 2011; Lusk et al., 2009; Mayer et al., 2003; Mayer et al., 2018; Mayer & Chandler, 2001; Mayer & Pilegard, 2014; Moreno, 2007; Spanjers et al., 2011; Stiller et al., 2009). However, it has been determined that the utilization of the segmenting principle may not be necessary in a single course. When faced with real-world resource constraints such as limited time and budget, instructional designers often need to make strategic decisions. In order to address these constraints, designers and educators may choose not to implement the segmenting principle, thereby reducing the required design and development time. Breaking up an already short lesson into segments may not significantly enhance the learner's learning experience. Based on the results of this research question, it was concluded that the incorporation of the segmenting principle did not yield significant learning benefits. Therefore, instructional designers and educators may choose to conserve resources, time, and financial investments by opting not to include segmenting principle in their instruction.

Recommendations for Future Research. As previously discussed, future studies may benefit from utilizing a larger sample size to enhance the generalizability of the findings. Additionally, selecting more complex instructional topics can provide a greater challenge for participants and offer a more comprehensive evaluation of the segmenting principle. Furthermore, incorporating more rigorous and demanding instruments can help assess the impact of the segmenting principle on learning outcomes. Moreover, exploring the effect of the segmenting principle on delayed transfer would provide valuable insights into its long-term effectiveness.

Research Question 3

Research question 3 and its sub-problems aim to explore the interaction effects between various combinations of modality and segmenting principles.

3. Are there statistically significant interaction effects of using different combinations of modality and segmenting principles on students' learning?

The results of this study indicated that there were no statistically significant differences among the four groups ($p > .05$). Thus, the study did not find any evidence to suggest that any of the treatments had an impact on overall, recall, and transfer test scores. Further analysis and discussion of these findings will be presented in the following sub-questions of research question 3.

Research Question 3.1. Research question 3.1 and two following sup-questions examined the statistically significant difference in overall, recall, and transfer posttest scores between the C and S groups.

3.1. Does using the segmenting principle alone improve overall learning versus using neither principle?

3.1.1. Does using the segmenting principle alone improve recall learning versus using neither principle?

3.1.2. Does using the segmenting principle alone improve transfer learning versus using neither principle?

The results showed there are no significant differences between the control and segmenting alone groups' overall, recall, and transfer scores. The most direct interpretation of this finding is that the overall, recall, and transfer posttest scores were not affected by the segmenting principle compared to the control group.

The findings of this study suggest that the use of segmenting principles alone, involving the breaking of lessons into smaller segments, did not effectively manage intrinsic loads compared to regular courses that did not employ any principle. This conclusion challenges the prevailing body of research on the use of segmenting principles alone in various studies (Ayres, 2006; Boucheix & Schneider, 2009; Chung et al., 2015; Hasler et al., 2007; Hassanabadi et al., 2011; Lusk et al., 2009; Mayer et al., 2003; Mayer et al., 2018; Mayer & Chandler, 2001; Mayer & Pilegard, 2014; Moreno, 2007; Spanjers et al., 2011; Stiller et al., 2009). Several potential factors in this study may have contributed to these divergent outcomes in comparison to previous research.

As previously discussed, the current study was subject to limitations, including a small sample size, brief treatment duration, and the presence of ceiling effects. The observed ceiling effects in this study may be attributed to several factors, such as the simplicity of the measurement instrument, the effectiveness of the instructional intervention, and participants' pre-existing knowledge. These factors offer plausible explanations for the lack of a significant segmenting effect observed in this study. These reasons are almost the same as previously mentioned because the individual group comparison has the same result as the main effect research questions.

Recommendations for Future Practice. Previous research has demonstrated the effective of utilizing segmenting alone (Ayres, 2006; Boucheix & Schneider, 2009; Chung et al., 2015; Hasler et al., 2007; Hassanabadi et al., 2011; Lusk et al., 2009; Mayer et al., 2003; Mayer et al., 2018; Mayer & Chandler, 2001; Mayer & Pilegard, 2014; Moreno, 2007; Spanjers et al., 2011; Stiller et al., 2009). However, it has been determined that the utilization of the segmenting principle alone may not be necessary in a single course. Instructional designers and educators may choose not to implement the segmenting principle, thereby reducing the required design and development time. Breaking up an already short lesson into segments may not significantly enhance the learner's learning experience. Based on the results of this research question, it was concluded that the incorporation of the segmenting principle did not yield significant learning benefits. Therefore, instructional designers and educators may choose to conserve resources, time, and financial investments by opting not to include the segmenting principle in their instruction.

Recommendations for Future Research. As discussed earlier, future studies could benefit from employing a larger sample size to improve the generalizability of the findings. Furthermore, selecting more complex instructional topics would present participants with greater challenges and allow for a more comprehensive evaluation of the segmenting principle. Additionally, incorporating more rigorous and demanding instruments would facilitate the assessment of the impact of the segmenting principle on learning outcomes. Moreover, investigating the effect of the segmenting principle on delayed transfer would provide valuable insights into its long-term effectiveness.

Research Question 3.2. Research question 3.2 and two following sup-questions examined the statistically significant difference in overall, recall, and transfer posttest scores between the C and M groups.

3.2. Does using the modality principle alone improve overall learning versus using neither principle?

- 3.2.1. Does using the modality principle alone improve recall learning versus using neither principle?
- 3.2.2. Does using the modality principle alone improve transfer learning versus using neither principle?

The results showed there are no significant differences between the C and M groups' overall, recall, and transfer scores. The most direct interpretation of this finding was that the overall, recall, and transfer posttest scores were not affected by the modality principle used in the treatments compared to the control group.

These findings suggest that the utilization of modality principles alone in instruction did not effectively manage intrinsic loads. This conclusion aligns with three research studies

(McNeill et al., 2009; Oberfoell & Correia, 2016; Tabbers et al., 2004) but contradicts the majority of previous research on the use of modality principles alone in various studies (AbuSaada et al., 2013; Aldalalah et al., 2010; Atkinson, 2002; Chuang & Ku, 2011; Clark & Mayer, 2016; Dubois & Vial, 2000; Fiorella et al., 2012; Harskamp et al., 2007; Ioannou, Rodiou, & Iliou, 2017; Mayer & Moreno, 1998; Moreno et al., 2001; Moreno & Mayer, 1999; Moreno & Mayer, 2002; Mousavi et al., 1995; Seufert et al., 2009; Tindall-Ford et al., 1997; Wouters et al., 2009). Several possible reasons in this study may have contributed to these results, which differed from the majority of previous research.

The current study had limitations, including a small sample size, brief treatment duration, and the presence of ceiling effects. The observed ceiling effects may be attributed to factors such as the simplicity of the measurement instrument, the effectiveness of the instructional intervention, and participants' pre-existing knowledge. These factors provide plausible explanations for the absence of a significant segmenting effect in the study. Because the individual group comparison has the same result as the main effect research questions, the reasons are almost the same as previously mentioned.

Recommendations for Future Practice. Previous research has demonstrated the effective of utilizing modality alone (AbuSaada et al., 2013; Aldalalah et al., 2010; Atkinson, 2002; Chuang & Ku, 2011; Clark & Mayer, 2016; Dubois & Vial, 2000; Fiorella et al., 2012; Harskamp et al., 2007; Ioannou, Rodiou, & Iliou, 2017; Mayer & Moreno, 1998; Moreno et al., 2001; Moreno & Mayer, 1999; Moreno & Mayer, 2002; Mousavi et al., 1995; Seufert et al., 2009; Tindall-Ford et al., 1997; Wouters et al., 2009). However, it has been determined that the utilization of the modality principle alone may not have been necessary in a single course. Instructional designers and educators may have chosen not to implement the modality principle, thereby reducing the required design and development time. Adding audio to short multimedia may not have significantly enhanced the students' learning experience. Based on the results of this research question, it was concluded that the incorporation of the modality principle did not yield significant learning benefits. Therefore, instructional designers and educators may have chosen to conserve resources, time, and financial investments by opting not to include the modality principle in their instruction.

Recommendations for Future Research. In order to enhance the generalizability of the findings, future studies should consider employing a larger sample size. Additionally, selecting instructional topics that are more complex would provide participants with greater challenges, allowing for a more comprehensive evaluation of the modality principle. Furthermore, the use of more rigorous and demanding instruments would facilitate a more accurate assessment of the impact of the modality principle on learning outcomes. Lastly, investigating the effect of the modality principle on delayed transfer would provide valuable insights into its long-term effectiveness.

Research Question 3.3. Research question 3.3 and two following sup-questions examined the statistically significant difference in overall, recall, and transfer posttest scores between using the modality principle alone and the segmenting principle alone.

3.3. Is there a difference between students’ overall learning when taught with the modality principle alone versus the segmenting principle alone?

- 3.3.1. Is there a difference between students’ recall learning when taught with the modality principle alone versus the segmenting principle alone?
- 3.3.2. Is there a difference between students’ transfer learning when taught with the modality principle alone versus the segmenting principle alone?

The results of the study indicated that there were no statistically significant differences in overall, recall, and transfer posttest scores between the utilization of the modality principle and the segmenting principle. These findings suggest that the specific implementation of either the modality principle or the segmenting principle in the treatments did not have a significant impact on the overall, recall, and transfer posttest scores. This result is consistent with the findings of Mayer's (2014) study, which also reported no significant difference in the effect between the modality principle and the segmenting principle. The modality principle and the segmenting principle using in this study may or may not equally effective at reducing cognitive load.

It should be noted that the present study still had several limitations, as previously discussed, including a small sample size, a brief treatment duration, and the presence of ceiling effects. These observed ceiling effects may be attributed to factors such as the simplicity of the measurement instrument, the effectiveness of the instructional intervention, and participants' pre-existing knowledge. These factors offer plausible explanations for the lack of a significant segmenting effect in the study.

From the Mayer (2014) presentation of the effect sizes for modality and segmenting principles, segmenting and modality have almost exactly the same median effect size across a number of studies (modality is .75 and segmenting is .77). Therefore, they may not have any differential levels of effectiveness. This may be why this study detected similar results.

Recommendations for Future Practice. It has been determined that the choice between using the modality principle or the segmenting principle in teaching does not significantly impact the reduction of cognitive load. Both principles may be equally effective in this regard. Therefore, instructional designers and educators have the flexibility to select either the modality principle or the segmenting principle for their instruction. Based on the findings of this research question, it was concluded that the incorporation of either the modality principle or the segmenting principle may or may not yield equal learning benefits. The decision regarding which principle to use may vary depending on the specific instructional approach.

Recommendations for Future Research. To enhance the generalizability of the findings, future studies should consider employing a larger sample size. Additionally, researchers should focus on selecting instructional topics that are more complex, which would provide participants with greater challenges and allow for a more comprehensive evaluation. Furthermore, incorporating more rigorous and demanding instruments would facilitate a more accurate assessment of learning outcomes. Lastly, investigating the effect of the modality or segmenting principles on delayed transfer would provide valuable insights into its long-term effectiveness in promoting knowledge retention and transfer.

Research Question 3.4. Research question 3.4 and two following sup-questions examined the statistically significant difference in overall, recall, and transfer posttest scores between using the segmenting and modality principles together and using segmenting alone.

3.4. Does using both the segmenting and modality principles together increase overall learning compared to segmenting alone?

- 3.4.1. Does using both the segmenting and modality principles together increase recall learning compared to segmenting alone?
- 3.4.2. Does using both the segmenting and modality principles together increase transfer learning compared to segmenting alone?

The results showed the group using segmenting and modality principles together performed no differently than the group only using the segmenting principle on the overall, recall, and transfer posttest scores. This finding means that the overall, recall, and transfer posttest scores were not affected by using segmenting and modality principles together compared to segmenting alone in the treatments.

As previously mentioned, the present study was subject to certain limitations, including a small sample size, a brief treatment duration, and the presence of ceiling effects. The observed ceiling effects in this study may be attributed to factors such as the simplicity of the measurement instrument, the effectiveness of the instructional intervention, and participants' pre-existing knowledge. These factors provide plausible explanations for the lack of a significant segmenting effect observed in the study.

Since this research question compared modality and segmenting to segmenting alone, this could be attributed to the fact that the segmenting principle alone was sufficient to manage intrinsic load. This also means that adding the second principle may not have been needed if the segmenting principle had already accomplished the task. For this reason, the intrinsic load might not have needed to be managed twice, once by each principle.

However, this assumption reason may not apply to all forms of learners. Miller (1956) had an idea about the magic number 7 ± 2, which provided evidence for the capacity of short-term memory. Since the participants in this study were college students, they might have been able to retain a typical or large amount of knowledge (7 items or more) in their short-term memory. Using both principles at the same time may not have had a significant impact on their learning. However, for students with cognitive impairments, managing instruction to limit the maximum load on short-term memory to 5 or 6 items at any given time could be a useful adaptation to create instruction that effectively reduces their short-term memory demands.

Recommendations for Future Practice. Both modality and segmenting have shown research-based evidence to be effective on their own (AbuSaada et al., 2013; Aldalalah et al., 2010; Dubois and Vial, 2000; Harskamp et al., 2007; Hasler et al., 2007; Mayer et al., 2003; Mayer et al., 2018; Mayer & Chandler, 2001; Mayer & Pilegard, 2014; Moreno et al., 2001; Moreno, 2007; Moreno & Mayer, 1999; Tindall-Ford et al., 1997). However, it may not be necessary to use the two principles simultaneously in a single course because the application of one of the principle may manage intrinsic load sufficiently for most learners. Instructional designers may deal with resource constraints such as time and money in the real-world. To avoid these constraints, instructional designers and educators may not use modality and segmenting principles simultaneously so they can reduce design and development time for instructional design. Based on the results of this study, the combination of two principles did not result in more learning. Therefore, instructional designers and educators might save resources, time, and money by not applying both two principles in courses.

Since there were no improvements in student learning when applying a combination of the two principles over applying either modality or segmenting individually, it may be sufficient to apply only one of them for overall and transfer learning. If the results of this study are confirmed, it is recommended that instructional designers select to use either modality or segmenting alone instead of applying both principles. However, careful consideration of the overall goal is needed, as well as intentionally choosing when to apply which principle to better manage intrinsic load, since this study only taught about gear instruction.

Recommendations for Future Research. To enhance the generalizability of the findings, future studies should consider employing a larger sample size. Additionally, researchers should have focused on selecting instructional topics that were more complex, which would have provided participants with greater challenges and allowed for a more comprehensive evaluation. Furthermore, incorporating more rigorous and demanding instruments would have facilitated a more accurate assessment of learning outcomes. Investigating the effect of the modality and segmenting principles together on delayed transfer would have provided valuable insights into their long-term effectiveness in promoting knowledge retention and transfer. Lastly, future studies could examine the effect of using the modality and segmenting principles together learners with cognitive impairments.

Research Question 3.5. Research question 3.5 and two following sup-questions examined the statistically significant difference in overall, recall, and transfer posttest scores between using the segmenting and modality principles together and using modality alone.

3.5. Does using the segmenting and modality principles together increase overall learning compared to modality alone?

 3.5.1. Does using the segmenting and modality principles together increase recall learning compared to modality alone?

 3.5.2. Does using the segmenting and modality principles together increase transfer learning compared to modality alone?

The results showed the group using segmenting and modality principles together performed no differently than the group only using the modality principle on the overall, recall, and transfer posttest scores. This finding means that the overall, recall, and transfer posttest scores were not affected by using segmenting and modality principles together compared to modality alone in the treatments.

As previously mentioned, the present study was subject to certain limitations, including a small sample size, a brief treatment duration, and the presence of ceiling effects. The observed ceiling effects in this study may be attributed to factors such as the simplicity of the measurement instrument, the effectiveness of the instructional intervention, and participants' pre-existing knowledge. These factors provide plausible explanations for the lack of a significant segmenting effect observed in the study.

This could also be attributed to the fact that the modality principle alone was sufficient to manage intrinsic loads. This meant that adding the second principle may not have been needed if the modality principle had already managed the intrinsic load effectively. For this reason, the intrinsic load might not have needed to be managed twice. However, it is important to note that this possible reason may not apply to learners with cognitive impairments, as mentioned previously.

Recommendations for Future Practice. As mentioned before, it may not be necessary to use the two principles simultaneously in a single course. Instructional designers and educators may be able to avoid using modality and segmenting principles simultaneously in order to reduce design and development time. However, this may only be broadly recommended instructional designers if the finding that the combination of two principles did not result in more learning can be replicated in future research. Therefore, if this finding is confirmed, instructional designers and educators may save resources, time, and money by not providing both two principles in courses.

Recommendations for Future Research. To enhance the generalizability of the findings, it is recommended that future studies incorporate a larger sample size. Additionally, researchers should give attention to selecting instructional topics of increased complexity to present participants with greater challenges, enabling a more comprehensive evaluation. Moreover, the inclusion of more rigorous and demanding instruments would enable a more precise assessment of learning outcomes. Valuable insights into the long-term effectiveness of promoting knowledge retention and transfer can be gained by investigating the combined impact of the modality and segmenting principles on delayed transfer. Lastly, examining the effect of using the modality and segmenting principles together on learning among learners with cognitive impairments would provide valuable information for instructional design practitioners. Perhaps the effects of combining two or more principles that reduce intrinsic on learners may be researched as a possible adaptation for special needs students.

Also, this study also did not examine motivation or other affective domain factors. Motivation, fatigue, self-efficacy, situational interest, or other affect factors could have impacted learning for a variety of reasons. Future research could replicate the study and incorporate motivational and affect factors that may influence posttest scores.

In the instructional design of the present study, students were unaware of the course progress until they completed the final required activity. Consequently, students lacked information regarding the duration of the course and their progress within it. While this design may be suitable for short courses, such as the one in this study, the inclusion of a progress bar may be necessary for longer instructional sessions. By incorporating a progress bar, learners can gain a better understanding of their progress and module position. Therefore, it is recommended to consider implementing a progress bar in future lengthy instructions to mitigate learner fatigue and provide insights into the potential benefits of its usage. The introduction of a progress bar would inform students of their proximity to course completion, thus addressing the issue of fatigue.

This study compared only two of the principles that are thought to manage intrinsic load: segmenting and modality. Additional studies could examine the different combinations of the third principle like pretraining principle with either or both of segmenting and modality. This set of studies would be useful in determining the most effective combinations of segmenting, modality, and pretraining.

Summary

The findings of this study were inconsistent with a substantial body of prior research (AbuSaada et al., 2013; Aldalalah et al., 2010; Dubois and Vial, 2000; Harskamp et al., 2007; Hasler et al., 2007; Mayer et al., 2003; Mayer et al., 2018; Mayer & Chandler, 2001; Mayer & Pilegard, 2014; Moreno et al., 2001; Moreno, 2007; Moreno & Mayer, 1999; Tindall-Ford et al., 1997), as discussed above. Consequently, this chapter has prioritized examining the potential reasons behind this discrepancy instead of advocating for disregarding all previous research in this field.

Based on the findings from this study, further research is warranted to investigate the intricate relationship between modality and segmenting. While the current study's findings did not align with previous research indicating the effectiveness of these principles, it is important to conduct additional studies in varied research settings and with larger sample sizes. Additionally, exploring different combinations of these principles that may be effective for different types of learning is warranted. Continued research with multimedia principles should investigate various combinations of the modality and segmenting principles to expand our understanding of their efficacy.

The results of this study indicate the notion that "more is better" does not always hold true. Instructional designers, practitioners, and educators must thoughtfully consider the instructional strategies they employ and the contextual factors surrounding their implementation. Without considering the interplay between different strategies, learning outcomes may be hindered by the inclusion of multiple principles or strategies targeting the same objective. In the present study, the objective was to manage essential processing, yet employing additional principles to address this goal did not consistently yield optimal learning outcomes.

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Appendix A

Key Information About This Study Form

Key Information About This Study

- You are being invited to participate in a research study. Participation is completely voluntary.
- Study Purpose: We try to examine the influence of multimedia principles on students' learning performance in a lesson about gear systems.
- Main Activities for Research Participants: You will be asked to watch an instructional video about gear systems and complete some activities and a posttest.
- Time Required for Participation: This study will take approximately 30 minutes of your time.
- Significant Risks: There is a small chance that your personal information could be accidentally disclosed. We will do our best to protect your personal information.
- Potential Benefits: From this study, you will learn how gear systems work and the relationship between the number of teeth and the number of rotations from gear systems.

Appendix B

Consent Form

Consent Form

Purpose of the Study:

The purpose of this study will be to examine the influence of some multimedia principles on students' learning performance in a lesson about gear systems. In this study, student learning will be examined using the modality and segmenting principles independently and combined to determine if different combinations of these principles improve learning of the course content compared to the other combinations.

Study Sample:

We hope to include college students over 18 years old and no not experts in gear systems to participate in this study.

Who is doing this study:

Name: Barry Huang

Email: huanteng@isu.edu

Office Phone: (208) 282-2569

Name: David Coffland

Email: coffdavi@isu.edu

Office Phone: (208) 282-3658

What you would be asked to do:

You will be asked to watch instructional video about gear systems, complete some activities, and take a posttest. The total time of this research will be slightly under 30 minutes. There are four groups in this study. They are control group (C), modality principle group (M), segmenting principle group (S), and the modality and segmenting principles group (MS).

Control group (C):

Students in the C group will watch a long video (~5 minutes) with written subtitles and complete generative activities after watching the video.

Modality principle group (M):

Students in the M group will watch a long video (~5 minutes) with audio narration and do the generative activities after the video.

Segmenting principle group (S):

Students in the S group will watch four short (each ~1-2 minutes) videos with written subtitles and perform generative activities between each segment.

Modality and segmenting principles group (MS):

Students in the MS group will watch four short videos (each ~1-2 minutes) with audio narration and do the generative activities between each segment. Although these groups will receive different instructional methods, they will be taught the same content.

All groups will take the same posttest at the end. The group you will be assigned to will be chosen by chance, like flipping a coin. Neither you nor the study team will choose what intervention you get. You will have one in four chance of being assigned to any given group. You will not be told which group or intervention you are getting, however your study team will know.

Will being in this study help you?

From this study, you will learn how gear systems work and the relationship between the number of teeth and the number of rotations from gear systems.

Will you receive anything for participating in this study?

You will receive a $10 Amazon gift card for completing the study immediately after you finish the posttest. You will be asked to sign for your gift card but this will NOT connect to any of your data in the study.

If you start the study, do you have to complete it?

No, you may withdraw from the study at any time and your data will not be included in any way. However, only those who complete the study will receive the gift card mentioned above.

Will it cost you anything to be in this study?

This study will not cost you anything to participate.

Who will see your information:

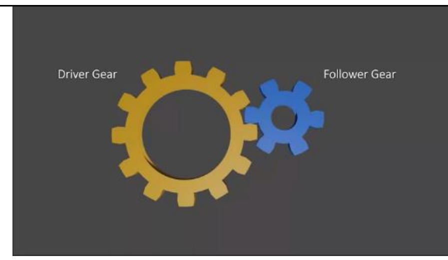
We need your consent to use your anonymous data from this in publications or presentations. Your name will never appear in any public or private discussion of results. The person in charge of the research study can remove you from the research study without your approval. Possible reasons for removal include providing incomplete data, false data, omitting answers, or withdrawing part way through the research study. The information or samples collected as part of this research will not be used or distributed for future research studies, even if all of your identifiers are removed.

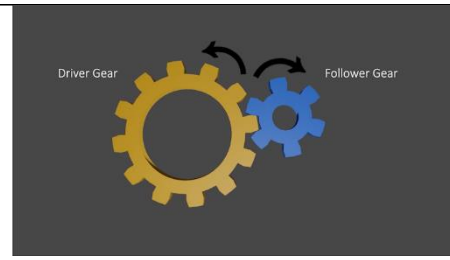
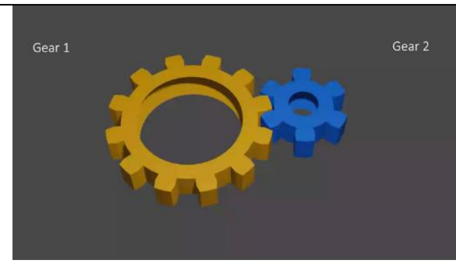
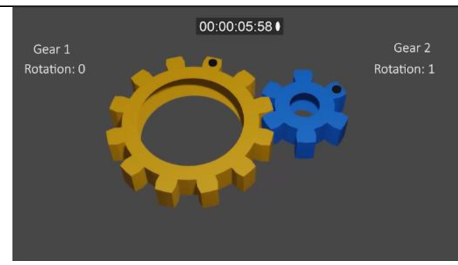
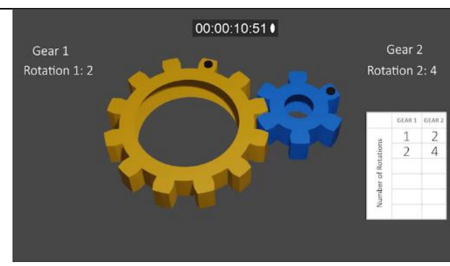
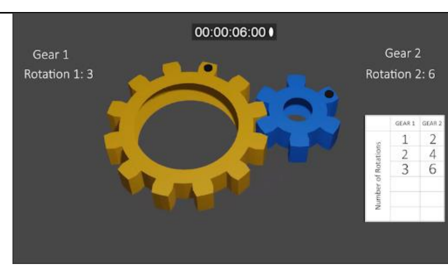
If you understand and agree to all of the above terms, please sign and date below:

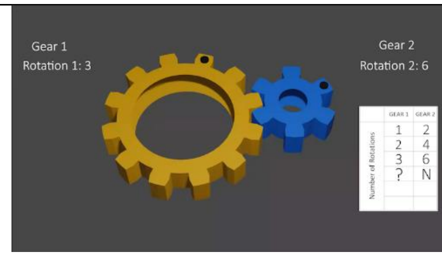
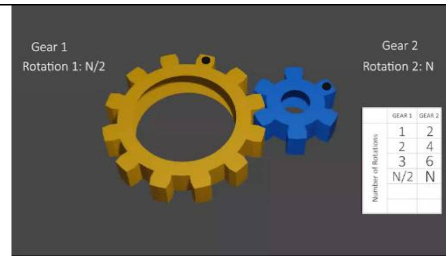
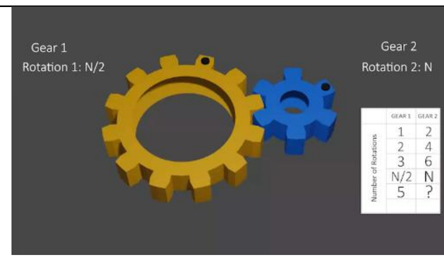
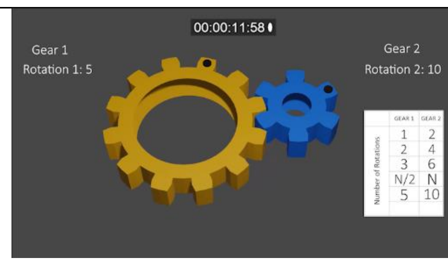
Signature________________________ Date________________

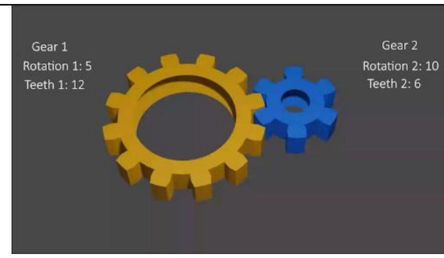
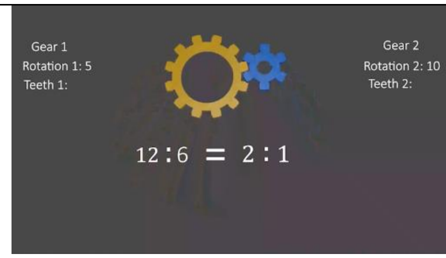
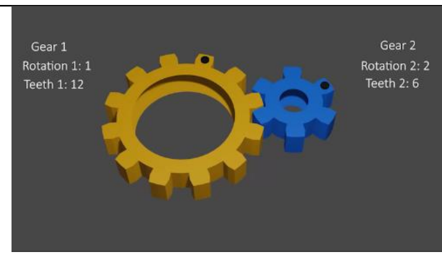
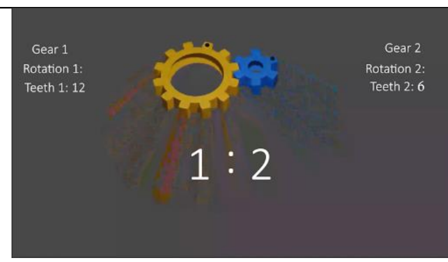
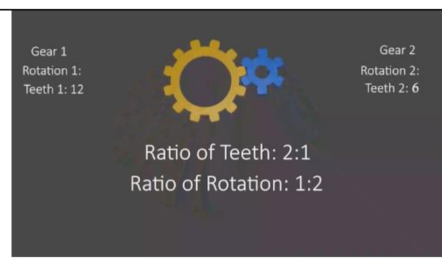
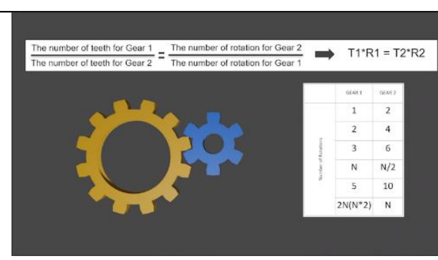
Appendix C

Content and Time of The Instructional Video

Time	Long	Subtitles	Screenshot
00:00:00	7s	When two gears fit together, one gear can turn another gear without slipping. This is a two-gear system.	
00:07:00	2s	A two-gear system has two parts.	
00:09:00	5s	The driver gear is the orange gear that turns first. The follower gear is the blue gear that turn by driver gear.	
00:14:30	3s	In this example, the driver gear has 12 teeth.	
00:18:30	3s	The follower gear has 6 teeth.	
00:21:21	9s	You should also notice that when we turn the driver gear clockwise, the follower gear turns anti-clockwise	

<table>
<tr><td>00:31:27</td><td>9s</td><td>Similarly, if we turn the driver gear anti-clockwise, the follower gear turns clockwise.</td><td>
</td></tr>
<tr><td>00:40:23</td><td>5s</td><td>From here on, the big, orange, driver gear will be called Gear 1, and the small, blue, follower gear will be called Gear 2.</td><td>
</td></tr>
<tr><td>00:45:37</td><td>12s</td><td>By observing the rotation of this gear system, you will find that the smaller gear always turns faster than the bigger gear.</td><td>
</td></tr>
<tr><td>00:55:47</td><td>13s</td><td>Here, you can also see that Gear 1 rotated 2 times when Gear 2 rotated 4 times.</td><td>
</td></tr>
<tr><td>01:08:34</td><td>7s</td><td>Now can you predict how many rotations Gear 1 will make when Gear 2 has rotation 6 times?</td><td>
</td></tr>
<tr><td>01:21:41</td><td>4s</td><td>The answer is if Gear 2 has rotated 6 times, the Gear 1 will have rotated 3 times.</td><td>
</td></tr>
</table>

<table>
<tr><td>01:25:45</td><td>7s</td><td>Can you also predict how many rotations Gear 1 will make when Gear 2 has rotation N times?</td><td>
</td></tr>
<tr><td>01:32:48</td><td>6s</td><td>The answer is if Gear 2 has rotated N times, the Gear 1 will have rotated N/2 times.</td><td>
</td></tr>
<tr><td>01:38:17</td><td>7s</td><td>Now let's think about it in reverse, can you predict how many rotations Gear 2 will make when Gear 1 has rotated 5 times?</td><td>
</td></tr>
<tr><td>01:55:29</td><td>4s</td><td>The answer is if Gear 1 has rotated 5 times, the Gear 2 will have rotated 10 times.</td><td>
</td></tr>
<tr><td>01:59:41</td><td>7s</td><td>Now, can you predict how many rotations Gear 2 will make when Gear 1 has rotation N times?</td><td>
</td></tr>
<tr><td>02:06:44</td><td>6s</td><td>The answer is if Gear 1 has rotated N times, the Gear 2 will have rotated N*2 or 2N times.</td><td>
</td></tr>
</table>

02:13:52	6s	As mentioned earlier, Gear 1 has 12 teeth and Gear 2 has 6 teeth.	
02:20:15	5s	In this case, the ratio of the teeth of this gear system should be 12:6 = 2:1	
02:28:35	8s	We also know Gear 1 rotates 1 time for every 2 rotation of Gear 2.	
02:36:07	6s	So, the ratio of rotations of this gear system is 1:2.	
02:47:03	7s	Here, you should notice that the ratio for the number of teeth (2:1) is the opposite of the ratio of the number of rotation (1:2).	
02:56:25	6s	From the above, we can infer an equation.	

Appendix D

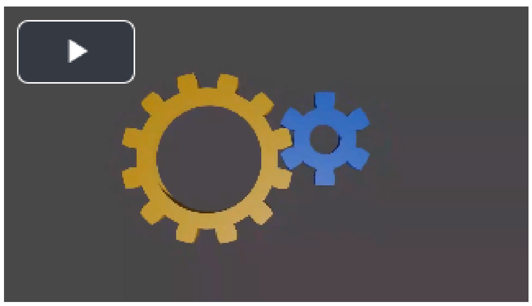
Moodle Course Outline

C Treatment

Group 1

Not available unless: You belong to **Group 1** (hidden otherwise)

Instructional Video



Mark as done

Activity 1: Direction of the Rotation
H5P
Mark as done
Not available unless: The activity **Instructional Video @@PLUGINFILE@...** is marked complete (hidden otherwise)

Activity 2: Find the Gear that Rotates in the Wrong Direction
H5P
Mark as done
Not available unless: The activity **Activity 1: Direction of the Rotation** is marked complete (hidden otherwise)

Activity 3: Sort Gears Based on Gear Rotation Speed
H5P
Mark as done
Not available unless: The activity **Activity 2: Find the Gear that Rotates in the Wrong Direction** is marked complete (hidden otherwise)

Activity 4: Find the Fastest Gear
H5P
Mark as done
Not available unless: The activity **Activity 3: Sort Gears Based on Gear Rotation Speed** is marked complete (hidden otherwise)

Activity 5: The ratio of gears' teeth
H5P
Mark as done
Not available unless: The activity **Activity 4: Find the Fastest Gear** is marked complete (hidden otherwise)

Activity 6: The ratio of Rotation
H5P
Mark as done

Not available unless: The activity **Activity 5: The ratio of gears' teeth** is marked complete (hidden otherwise)

Activity 7: Teeth and Rotation
H5P
Mark as done

Not available unless: The activity **Activity 6: The ratio of Rotation** is marked complete (hidden otherwise)

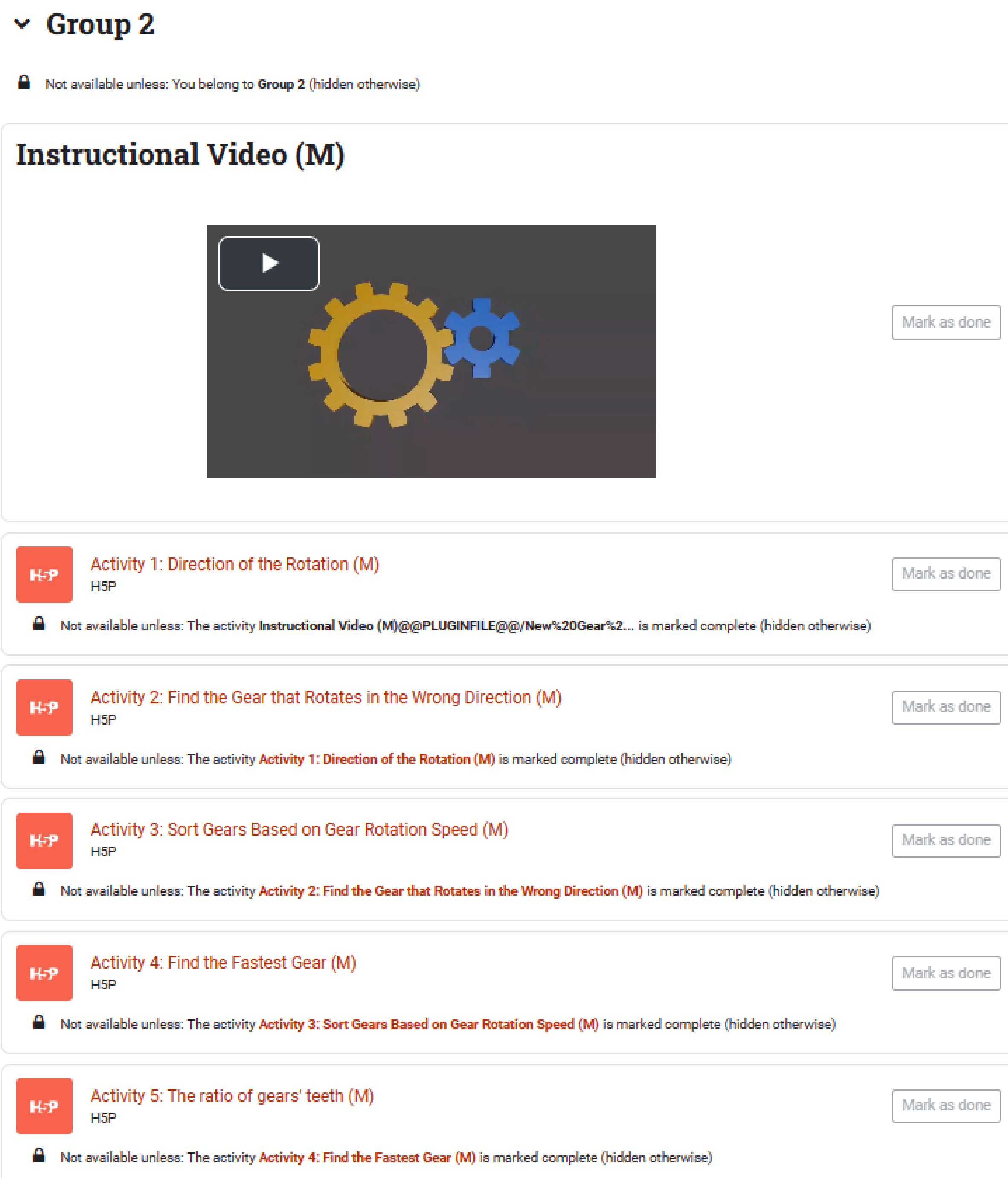
Activity 8: How many times will the orange gear rotate?
H5P
Mark as done

Not available unless: The activity **Activity 7: Teeth and Rotation** is marked complete (hidden otherwise)

Posttest
QUIZ
Mark as done

Not available unless: The activity **Activity 8: How many times will the orange gear rotate?** is marked complete (hidden otherwise)

M Treatment


Group 2
Not available unless: You belong to Group 2 (hidden otherwise)
Instructional Video (M)
Mark as done
Activity 1: Direction of the Rotation (M)
H5P
Mark as done
Not available unless: The activity Instructional Video (M)@@PLUGINFILE@@/New%20Gear%2... is marked complete (hidden otherwise)
Activity 2: Find the Gear that Rotates in the Wrong Direction (M)
H5P
Mark as done
Not available unless: The activity Activity 1: Direction of the Rotation (M) is marked complete (hidden otherwise)
Activity 3: Sort Gears Based on Gear Rotation Speed (M)
H5P
Mark as done
Not available unless: The activity Activity 2: Find the Gear that Rotates in the Wrong Direction (M) is marked complete (hidden otherwise)
Activity 4: Find the Fastest Gear (M)
H5P
Mark as done
Not available unless: The activity Activity 3: Sort Gears Based on Gear Rotation Speed (M) is marked complete (hidden otherwise)
Activity 5: The ratio of gears' teeth (M)
H5P
Mark as done
Not available unless: The activity Activity 4: Find the Fastest Gear (M) is marked complete (hidden otherwise)

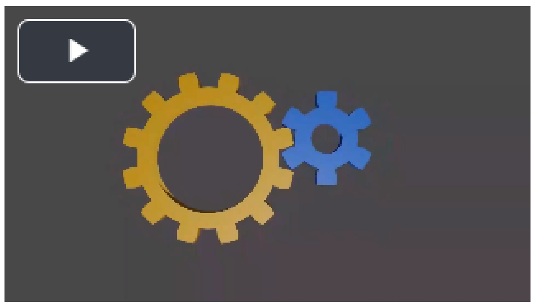

Activity 6: The ratio of Rotation (M)
H5P
Mark as done
Not available unless: The activity Activity 5: The ratio of gears' teeth (M) is marked complete (hidden otherwise)
Activity 7: Teeth and Rotation (M)
H5P
Mark as done
Not available unless: The activity Activity 6: The ratio of Rotation (M) is marked complete (hidden otherwise)
Activity 8: How many times will the orange gear rotate? (M)
H5P
Mark as done
Not available unless: The activity Activity 7: Teeth and Rotation (M) is marked complete (hidden otherwise)
Posttest (M)
QUIZ
Mark as done
Not available unless: The activity Activity 8: How many times will the orange gear rotate? (M) is marked complete (hidden otherwise)

S Treatment

Group 3

Not available unless: You belong to **Group 3** (hidden otherwise)

Instructional Video 1 (S)



Mark as done

Activity 1: Direction of the Rotation (S)
H5P

Mark as done

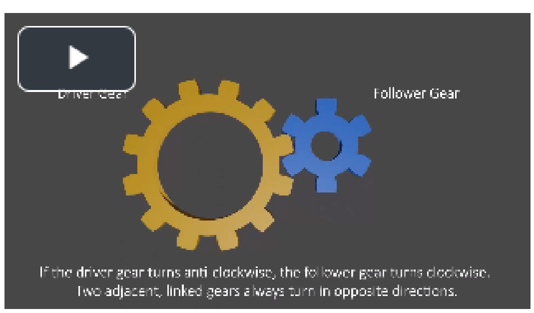
Not available unless: The activity **Instructional Video 1 (S) @@PLUGI...** is marked complete (hidden otherwise)

Activity 2: Find the Gear that Rotates in the Wrong Direction (S)
H5P

Mark as done

Not available unless: The activity **Instructional Video 1 (S) @@PLUGI...** is marked complete (hidden otherwise)

Instructional Video 2 (S)



Mark as done

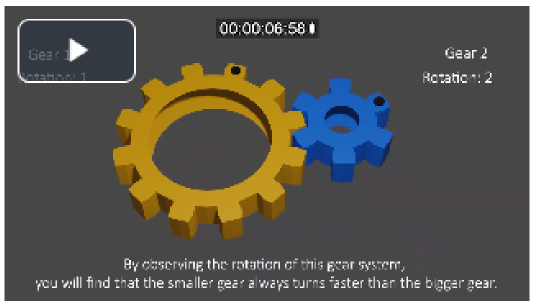
Activity 3: Sort Gears Based on Gear Rotation Speed (S)
H5P
Mark as done

Not available unless: The activity **Instructional Video 2 (S) @@PLUGI...** is marked complete (hidden otherwise)

Activity 4: Find the Fastest Gear (S)
H5P
Mark as done

Not available unless: The activity **Instructional Video 2 (S) @@PLUGI...** is marked complete (hidden otherwise)

Instructional Video 3 (S)



Mark as done

Not available unless: The activity **Activity 4: Find the Fastest Gear (S)** is marked complete (hidden otherwise)

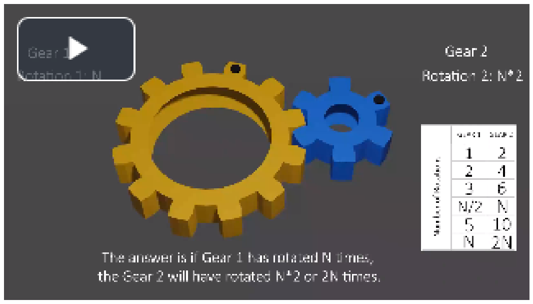
Activity 5: The ratio of gears' teeth (S)
H5P
Mark as done

Not available unless: The activity **Instructional Video 3 (S) @@PLUGI...** is marked complete (hidden otherwise)

Activity 6: The ratio of Rotation (S)
H5P
Mark as done

Not available unless: The activity **Instructional Video 3 (S) @@PLUGI...** is marked complete (hidden otherwise)

Instructional Video 4 (S)



Mark as done

Not available unless: The activity **Activity 6: The ratio of Rotation (S)** is marked complete (hidden otherwise)

Activity 7: Teeth and Rotation (S)
H5P

Mark as done

Not available unless: The activity **Instructional Video 4 (S) @@PLUGI...** is marked complete (hidden otherwise)

Activity 8: How many times will the orange gear rotate? (S)
H5P

Mark as done

Not available unless: The activity **Instructional Video 4 (S) @@PLUGI...** is marked complete (hidden otherwise)

Posttest (S)
QUIZ

Mark as done

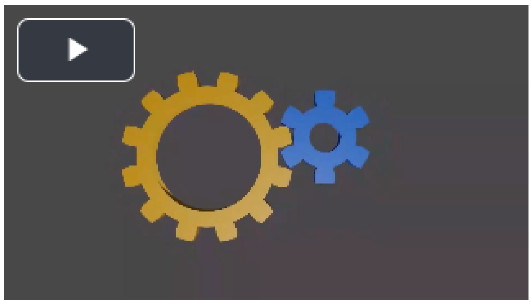
Not available unless: The activity **Activity 8: How many times will the orange gear rotate? (S)** is marked complete (hidden otherwise)

MS Treatment

Group 4

Not available unless: You belong to **Group 4** (hidden otherwise)

Instructional Video 1 (MS)



Mark as done

Activity 1: Direction of the Rotation (MS)
H5P

Mark as done

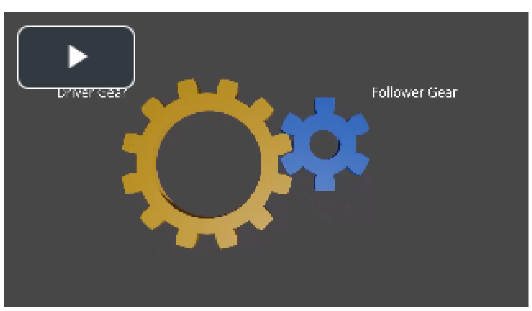
Not available unless: The activity **Instructional Video 1 (MS) @@PLUGINFILE@@/New...** is marked complete (hidden otherwise)

Activity 2: Find the Gear that Rotates in the Wrong Direction (MS)
H5P

Mark as done

Not available unless: The activity **Instructional Video 1 (MS) @@PLUGINFILE@@/New...** is marked complete (hidden otherwise)

Instructional Video 2 (MS)



Mark as done

Not available unless: The activity **Activity 2: Find the Gear that Rotates in the Wrong Direction (MS)** is marked complete (hidden otherwise)

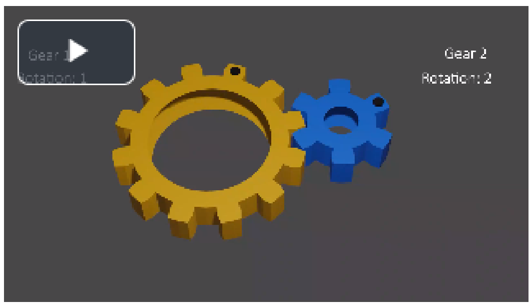
Activity 3: Sort Gears Based on Gear Rotation Speed (MS)
H5P
Mark as done

Not available unless: The activity **Instructional Video 2 (MS) @@PLUGINFILE@@/New...** is marked complete (hidden otherwise)

Activity 4: Find the Fastest Gear (MS)
H5P
Mark as done

Not available unless: The activity **Instructional Video 2 (MS) @@PLUGINFILE@@/New...** is marked complete (hidden otherwise)

Instructional Video 3 (MS)



Mark as done

Not available unless: The activity **Activity 4: Find the Fastest Gear (MS)** is marked complete (hidden otherwise)

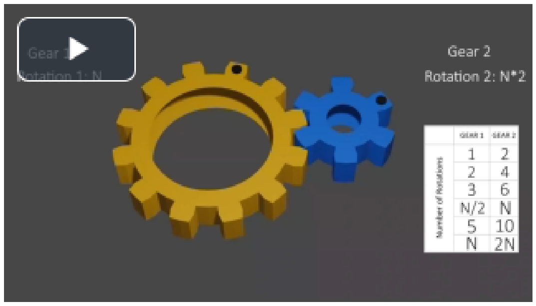
Activity 5: The ratio of gears' teeth (MS)
H5P
Mark as done

Not available unless: The activity **Instructional Video 3 (MS) @@PLUGINFILE@@/New...** is marked complete (hidden otherwise)

Activity 6: The ratio of Rotation (MS)
H5P
Mark as done

Not available unless: The activity **Instructional Video 3 (MS) @@PLUGINFILE@@/New...** is marked complete (hidden otherwise)

Instructional Video 4 (MS)



Mark as done

🔒 Not available unless: The activity **Activity 6: The ratio of Rotation (MS)** is marked complete (hidden otherwise)

Activity 7: Teeth and Rotation (MS)
H5P

Mark as done

🔒 Not available unless: The activity **Instructional Video 4 (MS) @@PLUGINFILE@@/New...** is marked complete (hidden otherwise)

Activity 8: How many times will the orange gear rotate? (MS)
H5P

Mark as done

🔒 Not available unless: The activity **Instructional Video 4 (MS) @@PLUGINFILE@@/New...** is marked complete (hidden otherwise)

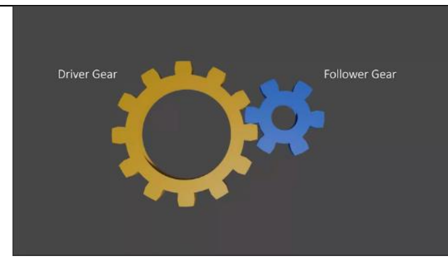
Posttest (MS)
QUIZ

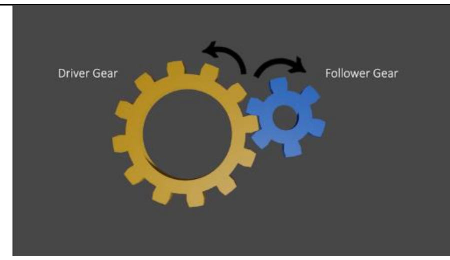
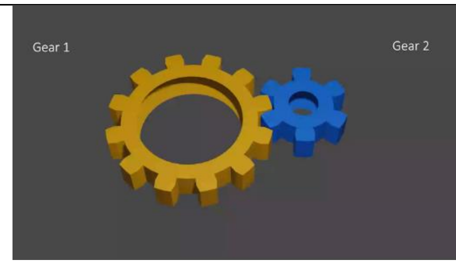
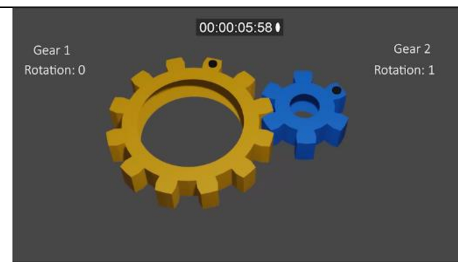
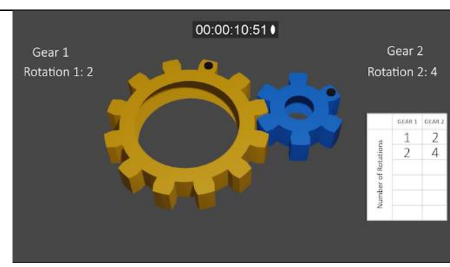
Mark as done

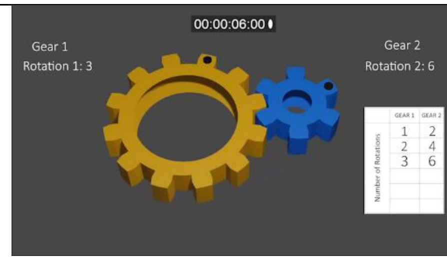
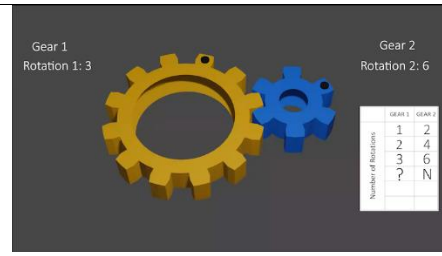
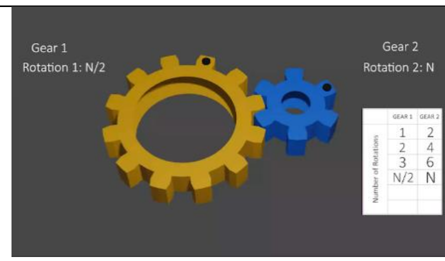
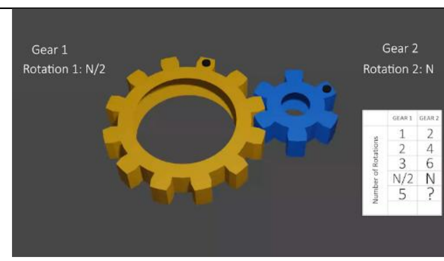
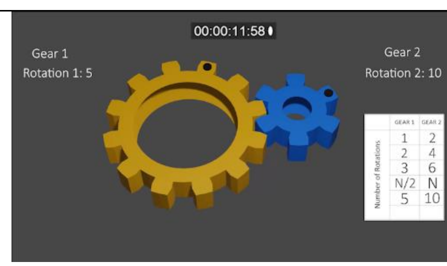
🔒 Not available unless: The activity **Activity 8: How many times will the orange gear rotate? (MS)** is marked complete (hidden otherwise)

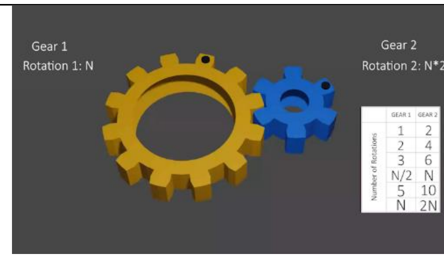
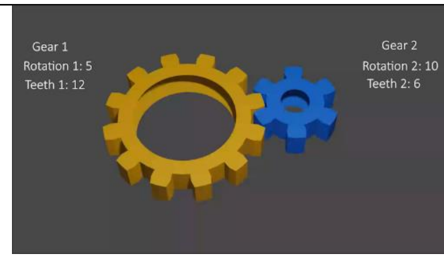
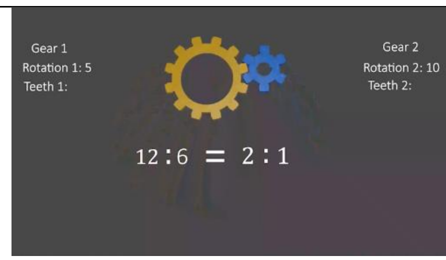
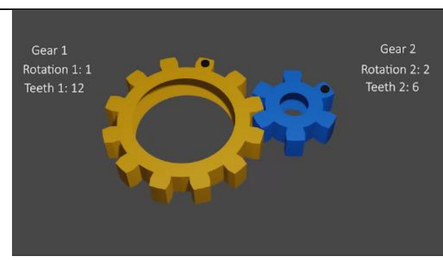
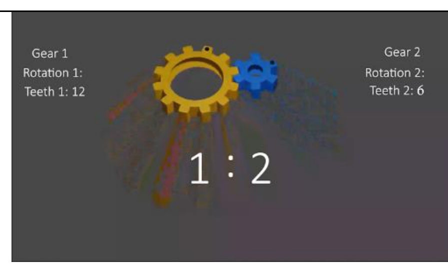
Appendix E

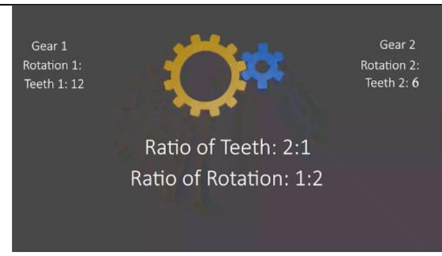
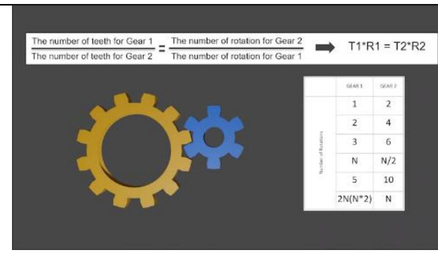
Content and Time of The Segmenting Instructional Video

Time	Long	Subtitles	Screenshot
00:00:00	7s	When two gears fit together, one gear can turn another gear without slipping. This is a two-gear system.	
00:07:00	2s	A two-gear system has two parts.	
00:09:00	5s	The driver gear is the orange gear that turns first. The follower gear is the blue gear that turn by driver gear.	
00:14:30	3s	In this example, the driver gear has 12 teeth.	
00:18:30	3s	The follower gear has 6 teeth.	
00:21:21	9s	You should also notice that when we turn the driver gear clockwise, the follower gear turns anti-clockwise	

00:31:27	9s	Similarly, if we turn the driver gear anti-clockwise, the follower gear turns clockwise.	
Segmenting break 1		Generative activity 1 and 2	
00:40:23	5s	From here on, the big, orange, driver gear will be called Gear 1, and the small, blue, follower gear will be called Gear 2.	
00:45:37	12s	By observing the rotation of this gear system, you will find that the smaller gear always turns faster than the bigger gear.	
Segmenting break 2		Generative activity 3 and 4	
00:55:47	13s	Here, you can also see that Gear 1 rotated 2 times when Gear 2 rotated 4 times.	
01:08:34	7s	Now can you predict how many rotations Gear 1 will make when Gear 2 has rotation 6 times?	

01:21:41	4s	The answer is if Gear 2 has rotated 6 times, the Gear 1 will have rotated 3 times.	
01:25:45	7s	Can you also predict how many rotations Gear 1 will make when Gear 2 has rotation N times?	
01:32:48	6s	The answer is if Gear 2 has rotated N times, the Gear 1 will have rotated N/2 times.	
01:38:17	7s	Now let's think about it in reverse, can you predict how many rotations Gear 2 will make when Gear 1 has rotated 5 times?	
01:55:29	4s	The answer is if Gear 1 has rotated 5 times, the Gear 2 will have rotated 10 times.	
01:59:41	7s	Now, can you predict how many rotations Gear 2 will make when Gear 1 has rotation N times?	

02:06:44	6s	The answer is if Gear 1 has rotated N times, the Gear 2 will have rotated N*2 or 2N times.	
Segmenting break 3		Generative activity 5 and 6	
02:13:52	6s	As mentioned earlier, Gear 1 has 12 teeth and Gear 2 has 6 teeth.	
02:20:15	5s	In this case, the ratio of the teeth of this gear system should be 12:6 = 2:1	
02:28:35	8s	We also know Gear 1 rotates 1 time for every 2 rotation of Gear 2.	
02:36:07	6s	So, the ratio of rotations of this gear system is 1:2.	

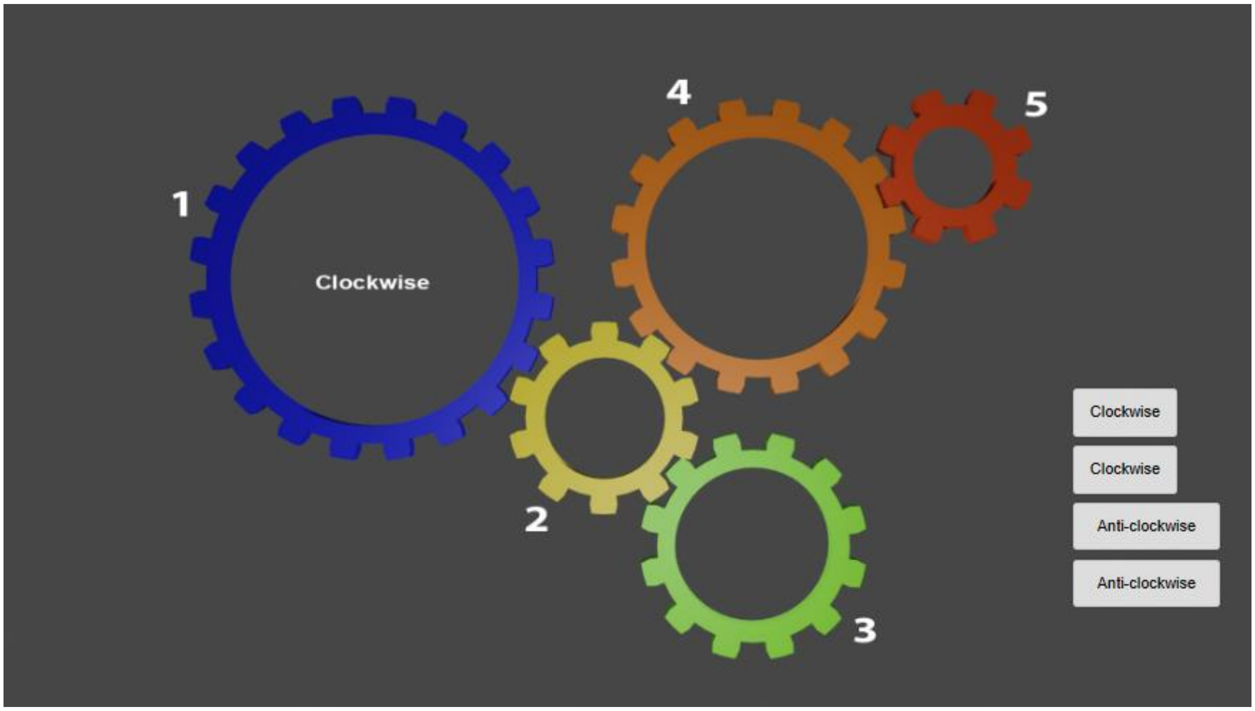
<table>
<tr><td>02:47:03</td><td>7s</td><td>Here, you should notice that the ratio for the number of teeth (2:1) is the opposite of the ratio of the number of rotation (1:2).</td><td></td></tr>
<tr><td colspan="2">Segmenting break 4</td><td>Generative activity 7 and 8</td><td></td></tr>
<tr><td>02:56:25</td><td>6s</td><td>From the above, we can infer an equation.</td><td></td></tr>
<tr><td colspan="4">Posttest</td></tr>
</table>

Appendix F

H5P Activities

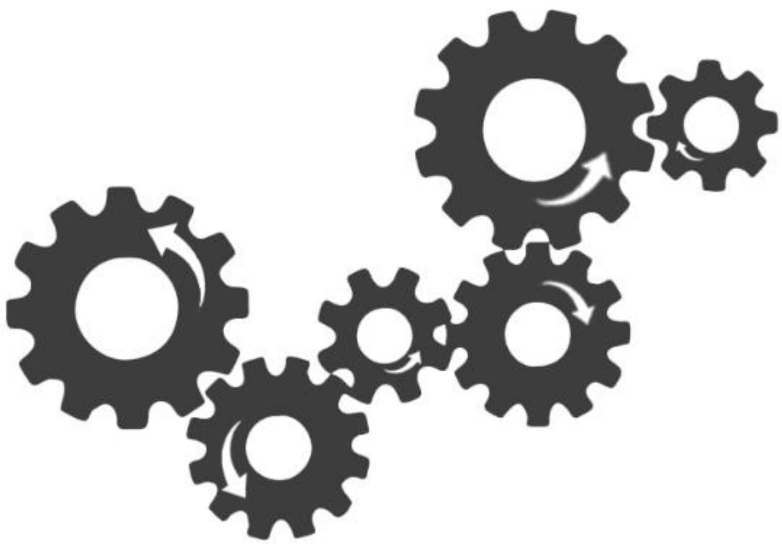
Activity 1: Direction of the Rotation

If you know gear 1 turns clockwise, please tell me the direction of the other gears. You can drag the correct answer to the corresponding gear.



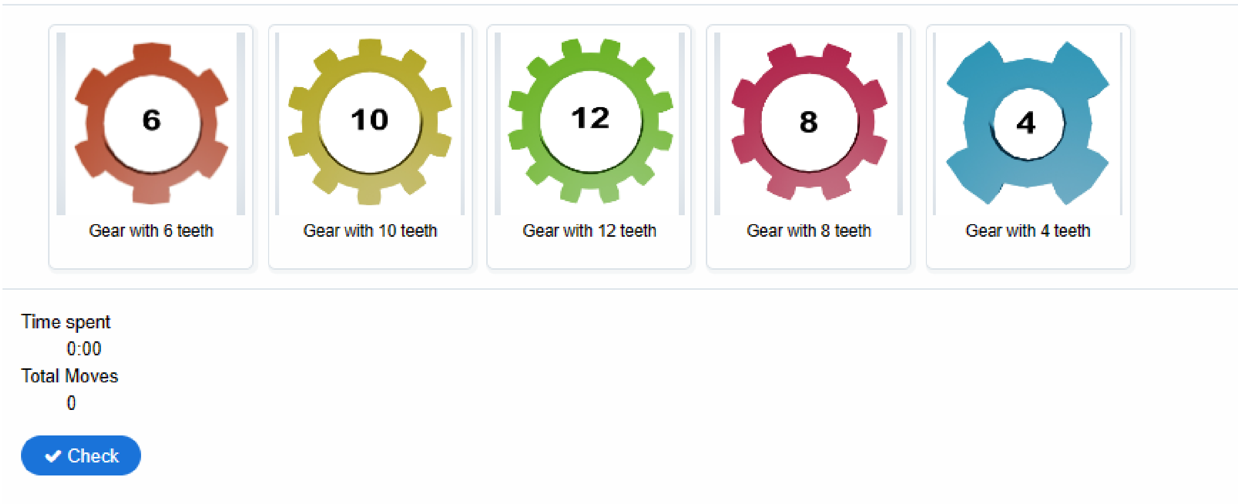
Activity 2: Find the Gear that Rotates in the Wrong Direction

In the gear system below, we already know that the first gear rotates anticlockwise. There is one gear below has an arrow indicating rotation in the wrong direction, please click on the gear you think has its arrow pointing in the wrong direction.



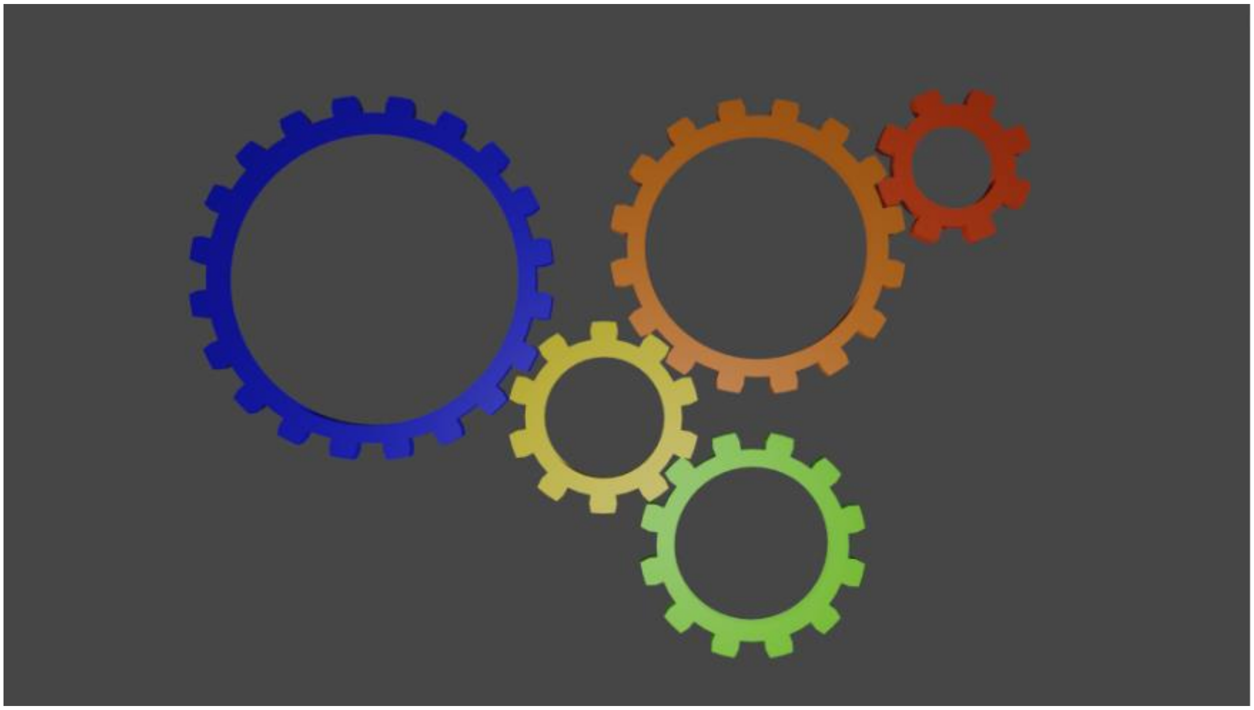
Activity 3: Sort Gears Based on Gear Rotation Speed

The gears below will rotate together in a single gear system. Please arrange the images in the correct sequence according to the rotation speed from fastest to slowest.



Activity 4: Find the Fastest Gear

If the following gear system rotates for 20 minutes, which gear will rotate the fastest? Click on the gear that you think rotates fastest.

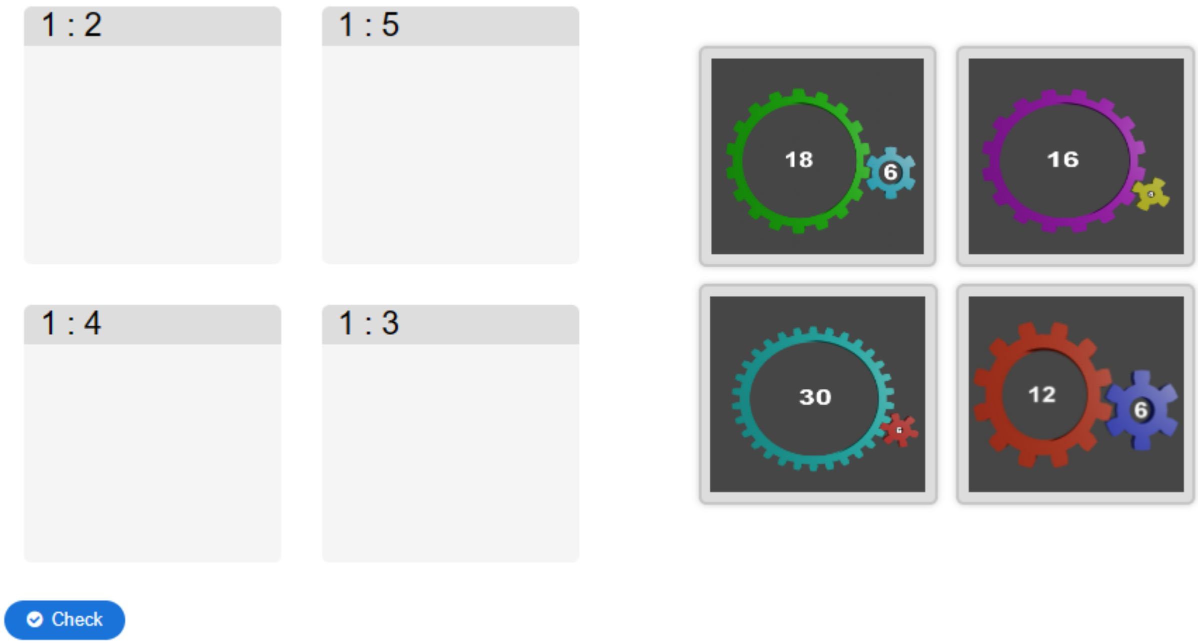


Activity 5: The ratio of gears' teeth

Each image shows a two-gear system with the number of teeth in each gear shown. Drag images from the left to match them with the corresponding ratio of teeth on the right.

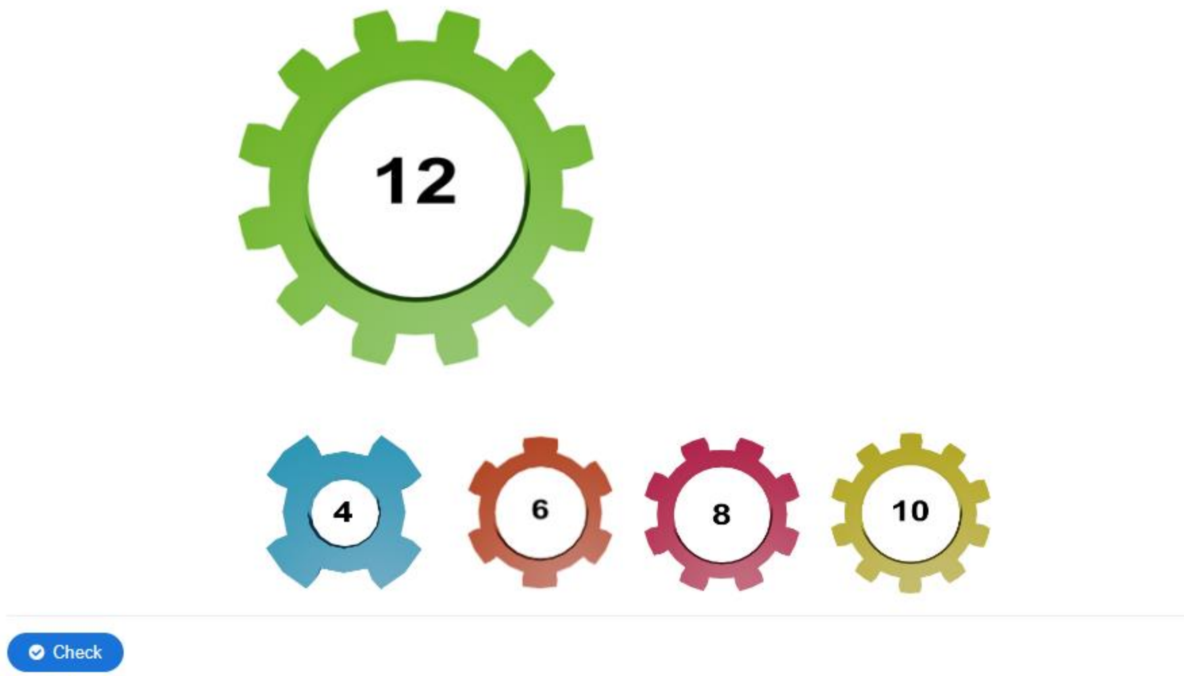
Activity 6: The ratio of Rotation

Please drag the picture on the right to match the corresponding rotation ratio on the left.



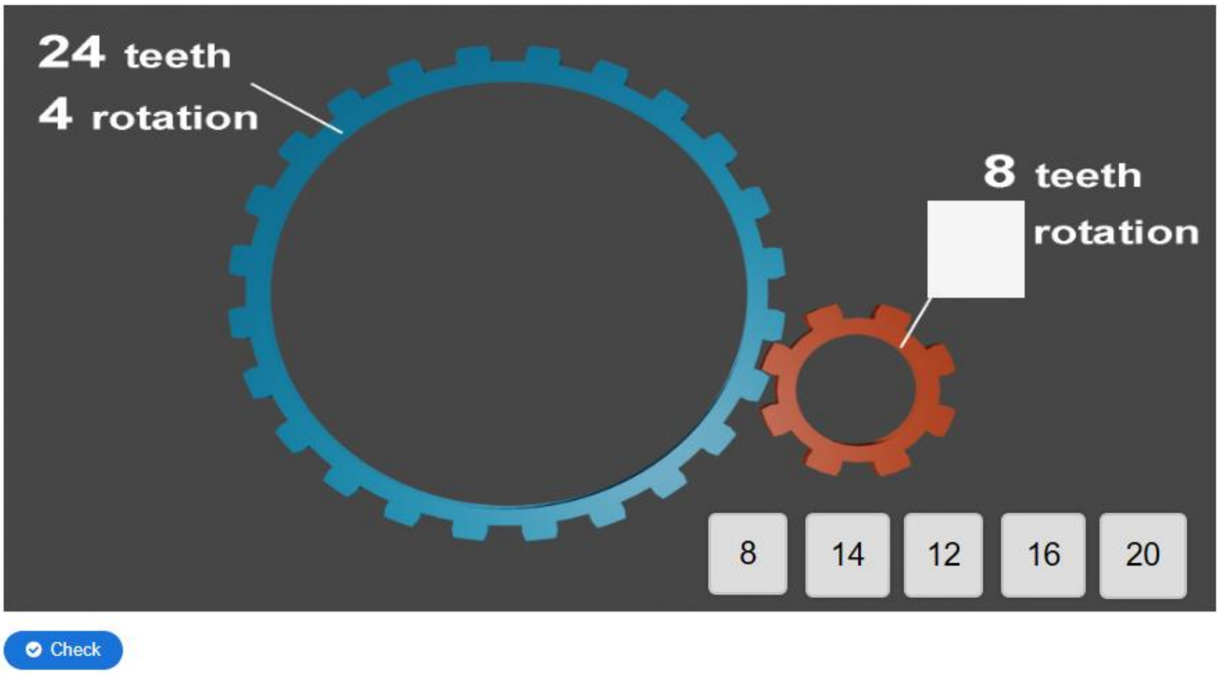
Activity 7: Teeth and Rotation

In a two-gear system, the green gear has 12 teeth. If the green gear rotates 3 times, the second gear rotates 6 times. Which of the following gears can be the second gear? Please drag the correct gear to the right of the green gear.



Activity 8: How many times will the orange gear rotate?

Examining the following gear system. If the blue gear rotates 4 times, how many times will the orange gear rotate?



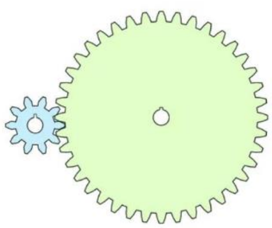
Appendix G

Recall and Transfer Posttest Questions

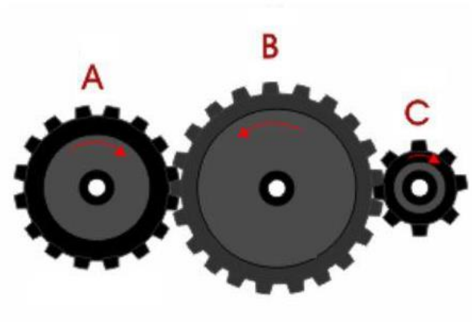
(T) mean transfer question, (R) mean recall question

1. **In a machine, if gear A is powered by an engine and rotates, gear B is powered by gear A and rotates. In this gear system: (T)**
    a. Gear A is follower gear and gear B is driver gear
    b. Gear A is driver gear and gear B is follower gear
    c. Both of them are follower gears
    d. Both of them are driver gears

2. **In this picture, which gear will turn faster? (R)**
    a. Green gear
    b. Blue gear

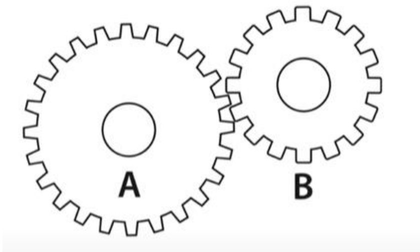


3. **In the gear system below, the order of rotation speed of these gears from fast to slow should be: (T)**



    a. gear A is the fastest, gear C is the second fastest, and gear B is the slowest
    b. gear B is the fastest, gear A is the second fastest, and gear C is the slowest
    c. gear C is the fastest, gear A is the second fastest, and gear B is the slowest
    d. gear C is the fastest, gear B is the second fastest, and gear A is the slowest

4. In the gear system below, which gear will make the most rotations in 30 minutes? (R)



a. Gear A will have the most rotations

b. Gear B will have the most rotations

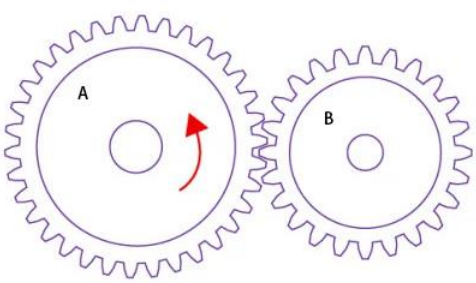
c. Both will have the same number of rotations

5. If gears are meshed (touching), then what direction are the adjacent gears moving? (R)

a. In the same direction

b. In opposite directions

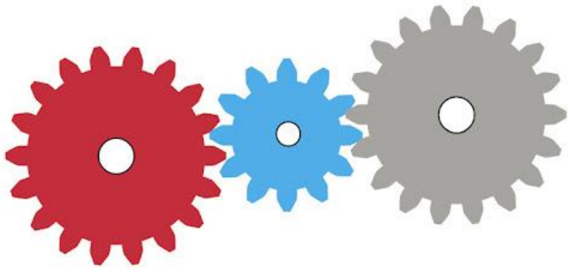
6. According to the gear system below, gear A rotates anticlockwise. What is the direction of rotation of gear B? (R)



a. Clockwise

b. Anticlockwise

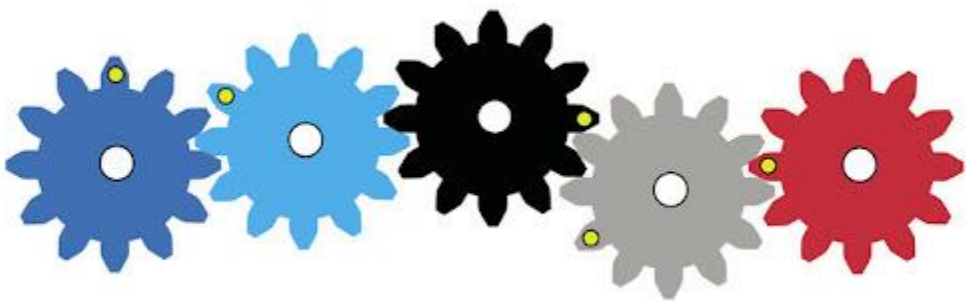
7. When the red gear rotates clockwise, what direction will the gray gear rotate? (T)



a. Clockwise

b. Anticlockwise

8. When the dark blue gear rotates clockwise, which two gears will rotate anticlockwise? (T)



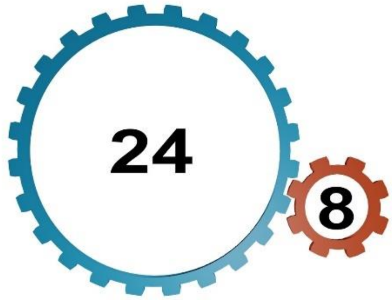
a. Light blue gear and red gear

b. Black gear and red gear

c. Light blue gear and gray gear

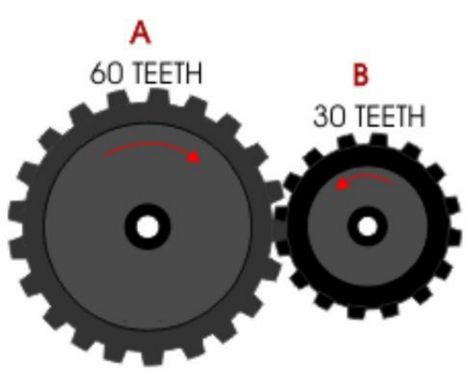
d. Black gear and gray gear

9. We already know the bigger gear has 24 teeth, and smaller gear has 8 teeth. If the big gear has rotated 4 times, how many times did the small gear rotate? (T)



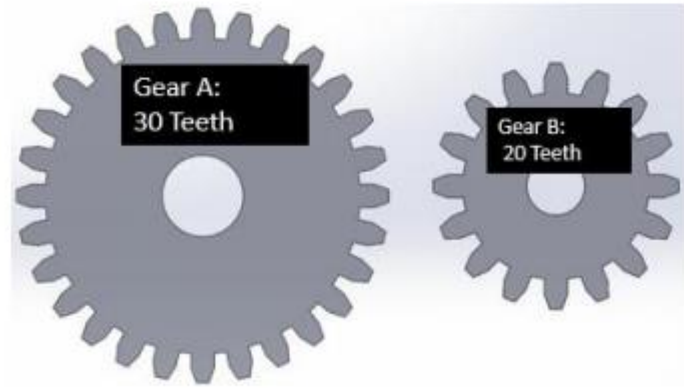
a. 12
b. 6
c. 3
d. 9

10. If you know gear A has 60 teeth and an gear B has 30 teeth, the ratio of gear teeth will be: (R)



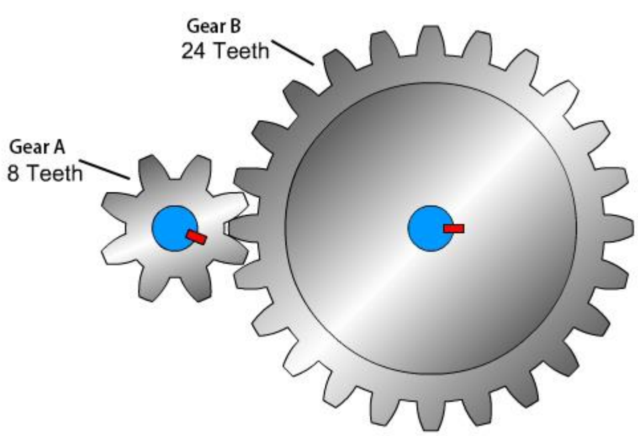
a. 1:2
b. 1:3
c. 3:1
d. 2:1

11. If gear A has rotated 40 times, how many times will gear B have rotated? (T)



a. 30
b. 20
c. 50
d. 60

12. According to the gear system below, the ratio of teeth of this gear system should be 1:3, what is the ratio of rotation for Gears A and B in this gear system? (R)



a. 2:1
b. 3:1
c. 1:2
d. 1:3