Integrating Hypothetical Learning Progression with Instructional Simulation in Earth Science: Assessment of Students' Performance, Learning Experiences, Self-Efficacy, and Metacognition

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The utilization of hypothetical learning progressions in science is a developmental approach that can help students create a more sophisticated understanding of the natural world. This study assessed sixty (60) Grade 8 high school students' learning progression in Earth Science. Using convergent parallel mixed method design (QUAL + QUAN), students' performance, learning experiences, self-efficacy and metacognition were investigated by collecting data such as qualitative essay and quantitative responses in Self-Efficacy and Metacognition Learning Inventory in Science (SEMLIS). The study showed students perceived meaningful learning experiences through simulation activities in earth science. Students' feedback reflects positive perceptions towards their learning experiences, and they were able to demonstrate evidence of attaining higher levels in the hypothetical paths. Pearson correlation analysis also showed significant links between Constructivist Connectivity and Monitoring, Evaluation, and Planning, Constructivist Connectivity and Self-Efficacy, and Constructivist Connectivity and Control of Concentration, indicating higher self-efficacy and concentration among students with strong knowledge construction skills. Additionally, correlations between Monitoring, Evaluation, and Planning, and Self-Efficacy, as well as Monitoring, Evaluation, and Planning, and Control of Concentration highlighted the importance of planning and evaluation in fostering self-efficacy and concentration.

Keywords: earth science, hypothetical learning progression, metacognition, self-efficacy, student achievement

Introduction

The dynamic nature of the 21st century curricula puts an emphasis on meaningful learning experiences. In these experiences, higher order thinking skills are developed and innovative minds are honed. This enables 21st century learners to tackle a wide range of issues, from multidisciplinary and transdisciplinary perspectives with the aid of technology (Vidergor, 2018). The design of current frameworks allows students' active engagement in the learning process. The early works of Kauffman (1976), Slaughter (1993), Dator (2002), and Gidley (2005) helped in the understanding future learners, who are now 21st century students, by foreseeing that educational philosophy and epistemology approach must be given an emphasis (Yeoman & McMahon-Beatte, 2018). The diverse pedagogical approaches in the 21st century learning focus on the development of essential skills called as the "7 Cs", which are: (1) critical thinking and problem solving; (2) communication; (3) collaboration; (4) computing and ICT; (5) career; (6) cross-cultural understanding; and (7) creativity and innovation (Trilling & Fadel, 2009; Vidergor, 2018). Envisioning what teaching and learning look like allows transformation of the learning process to meet the demands of the 21st century (Trilling & Fadel, 2009).

Learning progression in science education conceptualizes the following key components in a learning process: (1) the learning goals, (2) a developmental path for the thinking and learning process of learners at different levels, (3) and a set of learning activities appropriate for each level of thinking in which learners can actively engage to reach the goals. The term learning progression is also synonymous to hypothetical learning progression which is defined as "a route for students to move from more naive conceptions to a level of understanding closer to that of an expert", which is primarily based on the logic of the discipline (Simon, 1995; Anderson et al., 2012, Stevens et al., 2009, p. 02). In Mathematics education, the word trajectory is more commonly used than progression (Sztajn & Wilson, 2019).

Science education in the Philippines aims to equip learners with the ability to perform scientific processes and skills while demonstrating their understanding of scientific knowledge (Dalida, 2018; Department of Education, 2012). Central to this objective is the enhancement of students' competence in constructing scientific explanations (Kultusministerkonferenz, 2004; Ministry of Education, P. R. China, 2011; NGSS Leading States, 2013), which involves applying theoretical concepts to elucidate causal relationships or model the mechanisms of scientific phenomena (Braaten & Windschitl, 2011; National Research Council, 2012). Science, as a discipline, emphasizes active exploration of the natural world through inquiry-based approaches rather than merely memorizing static facts (Barber et al., 2022; AAAS, 1993; Bransford et al., 2000; Flavell, 1992; Metz, 1995, 2000; NRC, 1996).

As a Science discipline, Earth science exemplifies inquiry-based approach by focusing on the exploration and understanding of the dynamics of planet Earth. It encompasses the study of various spheres: atmosphere, hydrosphere, lithosphere, cryosphere, and biosphere, which sustain life and resources (Orion, 2019). Modern science education adopts interdisciplinary and multidisciplinary perspectives, along with a systems approach, to comprehensively study Earth and its surroundings (Orion, 2019). In the Philippine Basic Education science framework, Earth and Space are integrated subject areas covering core contents such as our surroundings, soil, water, air, weather, natural hazards, the dynamic Earth, and astronomy (SEI-DOST & UP NISMED, 2011). This framework is structured around three interconnected components: inquiry skills, scientific attitudes, and content and connections, facilitating the development of scientifically literate learners.

To support the cultivation of students' scientific literacy, science educators utilize a wide range of teaching approaches, including instructional simulations. Simulations involve creating instructional environments where learners interact within a virtual representation of reality, tailored to align with specific learning goals and objectives (Geelan, 2013; UNSW, 2018). This approach embodies experiential learning principles, emphasizing student-centered and constructivist classroom practices (Geelan, 2013). By integrating simulations into science teaching, educators provide interactive and authentic learning experiences where students can observe, investigate, and receive immediate feedback on complex scientific phenomena (Bell & Smetana, 2008).

Despite explanations being a common component of science education, many students continue to struggle with composing accurate scientific explanations even after years of studying the subject (McCubbin, 1984; McNeill et al., 2006). This difficulty is rooted from poor understanding of core scientific concepts and principles, in addition to the fact that the knowledge foundation itself cannot guarantee the ability to make a proper scientific explanation. It is suggested that intricate scientific practice like stating proper scientific explanation should deliberately be taught in a science classroom (Solomon 1986; McNeill et al., 2006). This explicit approach in teaching scientific explanation will need a framework for scaffolding students' progression towards achieving competency in making scientific explanations.

There are several limitations of relying solely on text-based or firsthand-experience-based approaches in science education. Firstly, exclusively using firsthand experiences may not afford learners sufficient opportunities for reflection and discourse, crucial for meaningful learning and connecting new knowledge to prior understandings (Flavell, 1992; Brown & Campione, 1994; Kouba & Champagne, 1998; Metz, 2000; Flavell et al., 2001). Secondly, not all science concepts are directly observable; some are inaccessible due to size, hazardous nature, cost, or distance, making text-based approaches necessary for accessing such knowledge (Palincsar & Magnusson, 2001; Donovan & Smolkin, 2002; Duke & Bennett-Armistead, 2003). Additionally, science possesses its own language, logical reasoning structures, and communication styles, which are vital aspects represented through various means of scientific communication (Toulmin, 1958; Lemke, 1990; Kuhn, 1992; Duschl & Osborne, 2002; Yore et al., 2003). Lastly, scientists rely on secondhand sources of knowledge obtained from fellow researchers to enrich their investigations, demonstrating the importance of incorporating written and oral communication skills in science education (Haury, 1993; Hapgood et al., 2004; Osborne, 2004).

To address the limitations of text-based or firsthand-experience-based approaches in science education, instructional simulations emerge as a promising solution. Simulations are interactive computer programs that imitate how a specific system functions (Khan, 2010; Makamu & Ramnarain, 2022). By utilizing computer simulations, students can instantly observe the outcomes of virtual experiments, allowing ample time for discussion and collaboration with peers. Peffer et al. (2015) regard simulations as an innovative method for scaffolding science learning, enabling students to tackle complex tasks typically encountered in authentic learning environments. Consequently, this pedagogical approach holds the potential to facilitate transformative learning experiences that enhance scientific literacy (Quintana et al., 2004).

Although simulations are widely recognized for their benefits, there are limited studies that offer insights on their potential effects when integrated with learning progression frameworks. This gap leaves questions about how simulations can best complement and enhance the progression of student learning within various domains of knowledge. Exploring the potential benefits of integrating simulations into learning progression frameworks can amplify its effectiveness by offering interactive and immersive learning experiences aligned with specific learning goals at each stage of progression.

Literature Review

Hypothetical Learning Progression in Science Education

In an interview, physicist Richard Feynman (2010) stated that it is instinctive for learners to ask "why" questions. Educators play significant roles in transcending the learners' instinct into a competency of scientific explanation (Kultusministerkonferenz, 2004; Ministry of Education, P. R. China, 2011; NGSS Leading States, 2013). Competency evaluations like the OECD's Programme for International Student Assessment (PISA) puts emphasis to scientific explanations (OECD, 2013). The ability to provide explanatory accounts of natural phenomena is one of the three science-specific competencies that define scientific literacy in

PISA 2018. This competency allows learners to engage in critical discussion about scientific issues (OECD, 2019).

Yao et al. (2016) devised an initial framework for explicit explanation instruction. This initial framework is called *Claim-Evidence-Reasoning* (CER framework), which aims to guide students' competence in constructing scientific explanations. This framework encourages students to formulate argumentations comprising a claim, supporting evidence, and reasoning to establish connections between evidence and claim, ultimately explaining phenomena. Building upon the CER framework, Gotwals & Songer (2013) applied a learning progression approach in elementary Biology, guiding students through progressive stages in constructing scientific explanations, from scaffolded simple levels to un-scaffolded complex levels. This iterative process involves students making claims, supporting them with relevant evidence, and providing reasoning to bridge the two. Together, the CER framework and learning progression represent the initial systematic effort to enhance students' competency in crafting scientific explanations (Yao et al., 2016; Gotwals et al., 2012; Songer & Gotwals, 2012).

Moreover, research suggests that the CER framework and learning progression are effective in guiding students in constructing scientific explanations at various entry points, as evidenced by significant improvements in students' conceptual understanding and reasoning abilities within well-scaffolded learning environments (McNeill et al., 2006; Songer et al., 2009).

Another framework by Yao et al. (2016) is the phenomenon, theories, data, reasoning or simply PTDR framework. In K-12 education, when students create scientific explanations, they identify the phenomenon to be explained, then look for theories and data that can be used to support the explanation and highlight the linkage between the materials used in explanation and the phenomenon needing explanation through reasoning. Through the PTDR framework, the hypothetical learning progression can be used to develop assessments, design instructional tools, and scaffold learning processes (Fortus et al., 2013).

Metacognition and Self-Efficacy

There are three constructs that have been recently identified in helping students organize their own learning: metacognition, self-efficacy and self-regulation (Cera et al., 2013). Metacognition concerns the awareness of one's own knowledge, which involves the control on acquisition, processing and storage of information in one's mind. In a metacognitive approach, Cavanaugh and Perlmutter (1982) proposed that there is a difference between knowing the cognitive functioning and controlling its mechanisms, which involves evaluating and monitoring of the learning process. This means that metacognition is not only about the knowledge of mental processes, but also it involves processes on the control and adjustment of the mechanisms during knowledge acquisition.

Metacognitive control consists of the following components: (1) self-instruction; (2) self-interrogation and (3) self-monitoring. Self-instruction involves strategical means (i.e. how, why, when) in acquiring knowledge. Self- interrogation is when the strategies used in knowledge acquisition are validated and lastly, self-monitoring is the timely control of the correct use of strategies implemented to perform the tasks (Brown, 1975; Cornoldi, 1990). Self-monitoring is essential in the metacognitive process because it plays a role in developing awareness on the progress and gaps of one's learning process (Serra & Metcalfe, 2009).

On self-efficacy, psychologist Albert Bandura was the first to study and define this concept. He described self-efficacy as the belief in one's own ability to motivate oneself, use cognitive resources, and perform the actions necessary to complete a task (Bandura, 1977; 1990). Furthermore, he emphasized that self-efficacy arises from various sources including past and vicarious experiences, imagination, encouragement, and one's physiological and emotional state (Cervone, 1989; Williams, 1995).

Several studies show a close relationship between metacognition and some concepts associated to self-efficacy, such as academic anxiety, the use of correct learning strategies, the challenge brought by completing a task, interest, and identification of learning objectives (Legg & Locker, 2009; Aydin, et al., 2011; Coutinho, 2008; Tella et al., 2009; Age, 2011). The relationships between awareness of one's own knowledge and self-efficacy are based on the belief that students facing difficulties in learning the concepts and in knowledge processing may have insufficient self-efficacy beliefs. Good self-efficacy beliefs, therefore, are predictors of high academic performance. On the contrary, students' poor performance may be due to the absence of necessary skills or inability to use such skills correctly. Therefore, the effective use of one's skills and the ability to regulate one's own learning is a basis of good cognitive performance (Bouffard-Bouchard et al., 1991).

According to Vygotsky's Sociocultural Development Theory (1978), self-regulation in learning involves an interplay between personal and social factors (Zimmerman, 1990; 2008). This means that while learners possess internal cognitive and metacognitive processes for regulating their own learning, these processes are also significantly influenced by social interactions and external factors within their learning environment. In classroom settings where collaborative learning activities are common, learners can observe, imitate, and internalize the self-regulatory behaviors of their peers. This process, known as co-regulation, involves learners supporting and guiding each other in monitoring and controlling their learning processes (Perry, 1998, 2013; Perry et al., 2018). In addition, socially shared regulation expands upon the idea of co-regulation by emphasizing the collective nature of learning regulation within groups. Learners collaboratively work together to achieve common learning objectives. This promotes a sense of shared responsibility and accountability among group members, fostering a supportive and conducive learning environment where they can scaffold and support each other's learning processes (McCaslin, 2009; Hadwin et al., 2018).

Scope and Limitation

This study focuses solely on evaluating Grade 8 students' academic performance, learning experiences, self-efficacy, and metacognition in the field of earth science. It also explores the integration of instructional simulations within a hypothetical learning progression framework. Specifically, the study delved into core content aligned with topics from the fourth quarter of the School Year (SY) 2021–2022, including the earth-moon-sun system and stars.

Research Questions

The COVID-19 pandemic forced teachers, administrators, students and parents to adapt to a new educational context. This presents an opportunity to maximize available online resources, like instructional simulations, as well as common household materials, to enrich students' scientific skills and logical reasoning. Utilizing instructional simulations allows students to actively interact with the subject matter and derive enjoyment from the learning process within the familiar confines of their homes. In this study, the researcher aimed to answer the following questions:

1. What are the students' perceptions on their learning experience with the integrated use of hypothetical learning progression and instructional simulations?
2. What are the students' perceptions regarding their efficacy in utilizing integrated hypothetical learning progression and instructional simulations?
3. Is there a significant correlation between the five dimensions of the Self-Efficacy and Metacognition Learning Inventory in Science (SEMLIS) and students' final grade in earth science?

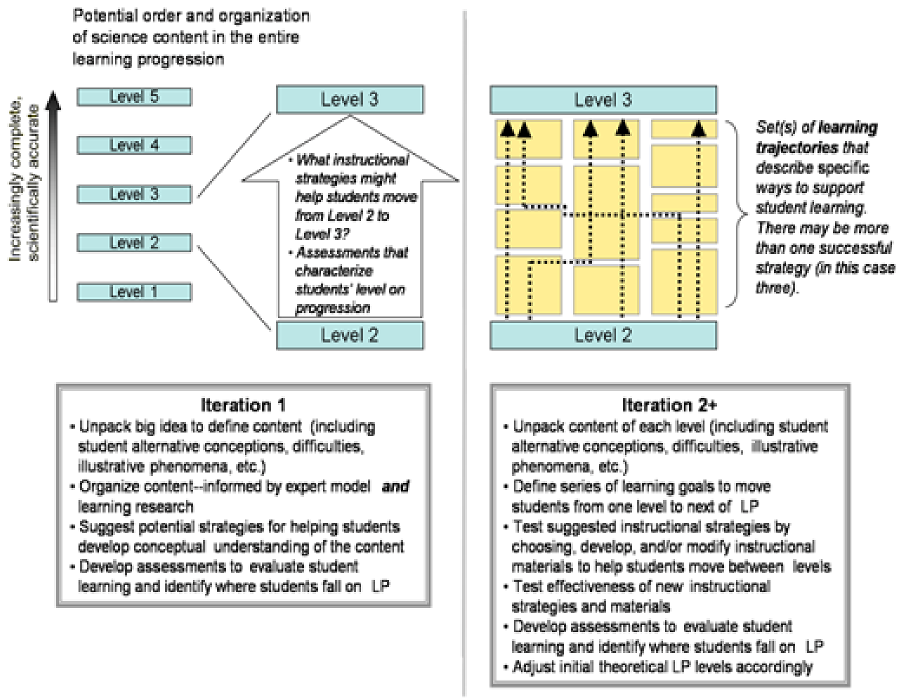
Methodology

Context of the Study and Participants

This study is a three-phase mixed method research, which primarily aims to explore the integration of hypothetical learning progression with simulations in teaching earth science, to help students develop and/or enhance their ability to make scientific explanations. The first phase is focused on the design and development of learning plans, in accordance with hypothetical learning progression design. Figure 1a present the hypothetical learning progression design by Stevens et al. (2009), which outlines a framework for understanding how students' knowledge and skills develop over time in a specific subject area. This design involves identifying key concepts and practices that students need to master, mapping out a sequence of learning experiences that build upon each other, and assessing students' progress at various stages.

Figure 1a

Hypothetical Learning Progression Design (Stevens et al., 2009)



In designing and developing the learning plans, initial steps entailed structuring the earth science content around the big ideas in science to ensure cohesive progression throughout the course. Illustrated in Figure 1a, two potential iterations were presented, indicating a refinement of the learning plans following empirical testing.

On the other hand, Figure 1b represents a portion of the hypothetical learning progression that was used in the development of learning plans. The figure depicts five levels of progression, each with corresponding competencies. Simulation tasks were integrated into levels 2 and 3. The teacher-made learning plans underwent thorough review and evaluation by peer cohorts within the educational field to ensure their effectiveness.

Figure 1b

Representation of a portion of the hypothetical learning progression for the earth-moon-sun system and stars (adapted from Stevens et al., 2009)

	Earth-moon-Sun System and Stars	Associated Simulation Tasks
Level 5	Students will synthesize knowledge of the earth-moon-sun system and stellar characteristics to explain astronomical phenomena, including star formation, stellar evolution, and galaxy formation, while applying mathematical concepts to calculate astronomical properties.	
Level 4	They will analyze observational data to formulate hypotheses and predictions about the universe's workings and critically evaluate scientific models and theories related to celestial phenomena based on evidence and observations.	
Level 3	Students will apply celestial mechanics to explain celestial body motion in the solar system, evaluate the significance of nuclear fusion in the Sun for sustaining life on Earth, interpret HR diagrams to analyze star characteristics and evolution, and investigate star formation, considering nebulae, gravity, and protostars in stellar birth.	Online simulation on stellar parallax Online simulation on doppler effect and redshift
Level 2	Students will analyze gravitational forces between the earth, moon, and sun, investigating their effects on tides and lunar phases. They will predict solar and lunar eclipses based on celestial positions and compare star characteristics such as size, brightness, temperature, and life cycle stages. Additionally, they will explain day and night, seasons, and lunar phases by understanding earth's rotation, revolution, and tilt.	Hands-on simulation on eclipses
Level 1	Students will identify the components of the earth-moon-sun system, recognize their relative positions and movements, and describe how the patterns of the moon's phases relate to the positions of the earth and sun.	

The second phase centers on implementing the learning plans through a Creative Responsibility-Based Learning (CRBL) approach, chosen as a primary instructional method during the COVID-19 pandemic. The learning plans were put into action over a six-week period.

Finally, the third phase involves assessing students' learning outcomes, self-efficacy, and metacognition following the integration of hypothetical learning progression and instructional simulations.

Research Participants

Research participants in this study were Grade 8 students from a science high school, all enrolled in earth science, totaling sixty (60) students.

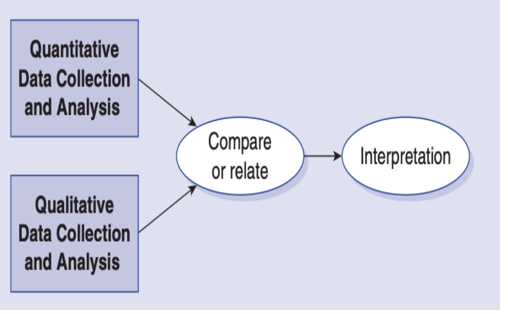
Research Design

This research utilized a convergent parallel design (QUAL + QUAN) in educational research (Figure 2). This design involves concurrent collection of qualitative and quantitative data during the same phase of a research process, and these data are analyzed independently. Qualitative data, such as students' responses to reflection questions, were gathered and analyzed, while quantitative data included students' 4th quarter grades in earth science and their responses to an inventory scale. The analysis were then "mixed" in the overall interpretation (Creswell et al., 2003; Creswell & Plano Clark, 2011).

Figure 2 illustrates the process of integrating quantitative and qualitative data in a research process. There are two distinct but parallel processes: quantitative data collection and analysis, and qualitative data collection and analysis. These two sets of data are then brought together for comparing or relating the findings. The analysis involves examining how the results from the quantitative analysis align with, complement, or contrast with the insights gained from the qualitative analysis. Lastly, the combined findings are interpreted to synthesize information from both data types, providing a comprehensive understanding of the research questions.

Figure 2

Convergent Parallel Design (Creswell & Plano Clark, 2003; 2011)



Data Collection Tools

a. Qualitative Data Collection

Reflection questions were administered at the conclusion of each session. These reflection questions aimed to capture students' perspectives on their learning experiences and efficacy. The qualitative analysis of these responses was conducted using MAXQDA software, which ensures precise data analysis by minimizing potential biases in interpretation. Through this method, the insights gleaned from students' reflections were carefully examined to inform further instructional refinement and improvement.

b. Quantitative Data Collection

To supplement the qualitative data on students' self-efficacy and metacognition, the *Self-Efficacy and Metacognition Learning Inventory in Science* (SEMLIS) by Thomas et al. (2007) was used to quantitatively measure students' self-efficacy and metacognition in learning earth science. Descriptive statistics such as mean and standard deviation were used to analyze the responses of the students on SEMLIS. Moreover, inferential statistics such as the Pearson Product-Moment Coefficient of Correlation was used to determine if there is a significant correlation between the students' self-efficacy and their final grade in earth science.

Protocol for the Conduct of the Study

This study underwent review by the Research Ethics Committee of the agency. Informed consent and assent forms were obtained from all participants prior to their involvement in the research.

a. Anonymity

This study only deals with the collection of qualitative and quantitative data such as students' responses on open-ended questionnaire (reflection questions), Science self-efficacy scale, and final grades in earth science. All data were de-identified hence no students' personal information such as name, class number and section, age, and gender were revealed.

b. Potential Risks

This only involves instructional practices commonly done in accepted educational settings. Since the main goal of integrating hypothetical learning progression with instructional simulations in teaching earth science is to develop and/or enrich the students' ability to create logical scientific explanations, this study does not have a negative impact on the students.

c. Role of the Researcher

The study ensures that only data that are aligned with the research questions were collected, analyzed, and reported. The data procurement was processed responsibly, and a final report is submitted to the agency on its completion.

Results

Students' Perceptions on their Learning Experiences

Students were given Reflection Questions in which the items aim to probe how students describe their experiences upon doing activities such as hands-on simulation of lunar eclipse by using materials that are commonly found at home, and online simulations that imitate the concept of stellar parallax and doppler effect.

Tables 1a to 1d show the thematic analysis of the students' perceptions on their learning experiences. Four converging themes emerged after analyzing students' responses through coding: (1) understand/understanding; (2) visualization; (3) learn/learning; and (4) activity. Each statement in the following themes were coded as follows:

- **Positive**
- **Slightly Positive**
- **Neutral**
- **Slightly Negative**
- **Negative**

Table 1a shows how students perceive their understanding of the lessons on stars and eclipses. About 85% of the responses indicate that students felt they comprehended the topics covered during the activities. This positive feedback suggests that the instructional methods employed were effective in facilitating student learning. However, approximately 5% of the students also gave negative responses, such as difficulties in understanding instructions, suggesting potential confusion regarding their understanding of the aforementioned topics. This feedback underscores the importance of clear and effective communication in facilitating student comprehension and learning outcomes.

On the second theme *Visualization*, students' perceptions reveal positive feedback regarding the efficacy of visual aids in enhancing learning experiences. These favorable perceptions imply that the use of simulations as visual representations facilitated students' understanding of astronomy

Table 1a

Students' perceptions on their understanding of the lessons

Theme: Understand/ Understanding
I still understand the associated concepts about stars, but I'm not sure if the simulation on Parallax and Doppler Effect helped me understand it more.
It helped me understand phenomena regarding the change of position of stars from earth's point of view.
It also helped me understand the reason why some stars appear to not move much while others move quite much.
Yes, both of these phenomena helped me better understand about stars and astronomy in general.
The Parallax activity helped me understand that certain measurements on the Earth can be made by observing the same celestial body like a star.
I feel that I did not understand the instructions well enough to know what was going on.
I do still think that the LG and researching helped me understand the lesson well enough though.
Yes, the activity helped me further understand eclipses.
The visual aspect of the worksheet allowed me to properly understand how eclipses happen and why they are so rare.
I still understand the associated concepts about stars, but I'm not sure if the simulation on Parallax and Doppler Effect helped me understand it more.
It helped me understand phenomena regarding the change of position of stars from earth's point of view.
It also helped me understand the reason why some stars appear to not move much while others move quite much.

Table 1b

Students' perceptions on the use of visualizations

Theme: Visualization
The visualization of the axis of the moon has made it easier to understand lunar eclipses and how they work
Because it gives me a better visualization of the three celestial bodies and their movements.
The slight tilt gave a visualization on how this works.
Better visualization of the three celestial bodies and their movements. It also helped me in building the idea of lunar eclipse.

concepts taught in class, enabling them to grasp scientific ideas more easily. This highlights the importance of incorporating visual elements into teaching practices to cater to diverse learning styles and enhance comprehension among students. By leveraging visualizations, educators can create more dynamic and engaging learning environments that promote deeper understanding and retention of subject matter.

Moreover, the students' positive perceptions of visualizations highlight the value of employing multimodal instructional approaches in teaching earth science. Visual aids offer a powerful means of complementing traditional teaching methods by providing additional context, clarity, and reinforcement of key concepts. Through visual representations, abstract astronomical phenomena can be rendered more tangible and accessible to students, fostering a deeper connection with the subject matter. Additionally, visualizations have the potential to promote active learning and critical thinking skills by encouraging students to analyze, interpret, and draw conclusions from visual data.

Table 1c shows the third theme *Learn/ Learning*, wherein students positively responded that they learned more about eclipses and stars through the activities used in class. A student further explained that visual examples helped them to enhance their comprehension, noting that these aids facilitated a more robust understanding compared to plain text only. The data reveal that the instructional activities can potentially foster deeper understanding of the celestial phenomena for a number of students in class.

This positive feedback emphasizes the effectiveness of the teaching methodologies employed, suggesting that the activities were engaging, informative, and conducive to learning.

Lastly, the students' perceptions on *Activity* shown in Table 1d reflects the students' positive views on learning activities. Table 1d further shows the summary of the connections between students' learning experiences and their understanding of the lessons, through visualizations and other learning activities integrated earth science lessons. To summarize, all details in Tables 1a-1d are visually reflected in Figures 3a and 3b, which highlight the most frequently used words/phrases by the students.

Table 1c

Students' perceptions on their learning

	Theme: Learn/Learning
●	The activity did help learn more about eclipses.
●	It made me learn more about how the moon, sun, and earth interact with each other to form these events.
●	…and more extensively the concepts about stars they were trying to teach and convey. Personally for me, I absolutely do learn more from visual examples rather than just plain text or words being presented to me. It's because of this I feel like that
●	learn more about how the moon, sun, and earth interact with each other to form these events. It also made me understand how eclipses function with….
●	learn more about eclipses. Since the activity was clear to understand and was very easy to make. It taught me that the moon's orbit isn't always straight.

Table 1d

Students' perceptions on learning activities

Theme: Activity
Yes, the activity helped me further my understanding.
The activity helped me visualize the tilt of the moon through a model.
As a result, the activity helped me understand why eclipses don't happen every month.
Yes I do believe this activity furthered my own understanding on the topic of eclipses.
Fortunately, this activity really explained the concept of it so simply but so well which really helped me understand what it was trying to convey.
Since the activity was clear to understand and was very easy to make.
The activity was easy to do.
Although it was quite a simple activity it has shown and given me a rough understanding and model of eclipses and other phases of the moon.
activity helped me visualize the tilt of the moon through a model. As a result, the activity helped me understand why eclipses don't happen every month
activity helped me to further understand eclipses. This is because it lets me visualize and interact with the model.
activity helped me gain a visual representation of the lunar eclipse which helped me further understand the lesson. It was fun and informative.
activity helped me understand the frequency of eclipses better in the sense that the Moon did not always fall on the Earth's flat shadow on the plate
activity helped me further understand eclipses. Because of the use of the ball and the paper plate, I was able to visualize when a lunar eclipse occur
activity helped visualize the process of the moon's orbit. It also helped me understand how the Earth's shadow works and why different phases of the moon…

Figure 3a

Word cloud of the Students' Responses on the question "Did the activity in Worksheet 18 Earth-Moon-Sun System help you further understand eclipses?

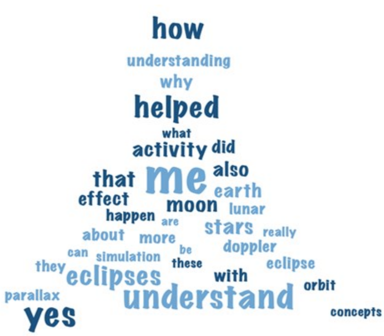
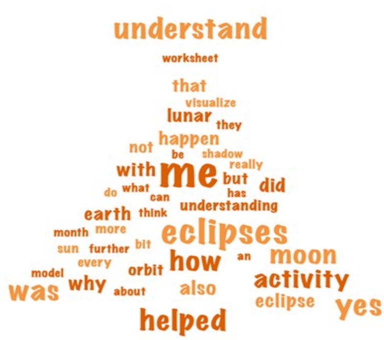


Figure 3b

Word Cloud of the Students' Responses on the question "Did the use of simulation on Parallax and Doppler Effect help you further understand certain concepts about starts?



In addition, Tables 2 and 3 below also shows students' responses on some of the *Reflection Questions* that they answered. Tables 2 and 3 further show that students were able to explain certain phenomena scientifically.

Table 2

Students' Responses on the Question "Why do Stars Differ in Brightness?"

Questions: Why do Stars Differ in Brightness?
Not all stars are created the same. Some may not only differ in mass but in composition as well. Age also plays a large role as older stars tend to be dimmer. If in the context of a specific location, then distance affects the brightness of the star too.
It depends on both the star itself and how far away from it we are. The more energy emitted by a star, the brighter it is. However, if a star is farther away from us, it looks dimmer to us.
Stars differ in brightness because of their size, temperature, and distance from the observer. The higher the surface area, the higher the light being given off. Hotter stars are also brighter. The distance of the star from the observer is also a factor since light will spread out over time and will get dimmer.
From my understanding, the reason why stars differ in brightness is because of both their distance to us as well as their luminosity. First of all, luminosity, the amount of energy radiated by a star, is actually determined by both the temperature as well as radius size of the star, so we can already see that stars have varying luminosity because of their varying temperature and radius size. Aside from luminosity, the distance of a star to us also changes the brightness of the star from our point of view, with stars closer to us being brighter than stars farther away from us. It is because of the varying luminosity as well as the varying distances between us and the many stars in space which gives stars differing brightness.
The distance of the star varies with brightness since some stars can be of the same size, but shine out dimmer due to how far it is. On the other hand, some stars could be of the same distance but be of different sizes and thus shine brighter. It depends on the temperature of the stars too in general. The hotter a star is, the bluer it gets. The bluer lights of stars have a higher frequency and are more powerful than those that fall on red on the electromagnetic spectrum of visible light.
First of all, some stars are farther away from us, so in our subjective view, they can be really dim even if they are more massive and hotter. The sun, for example is only a medium sized main sequence star but for us, it is the brightest object in the sky even when objectively, Sirius, another star is more luminous and hotter. Second, the color of the star decides its temperature (and by extension, brightness), the bluer a star, the higher its temperature, the brighter it is objectively.
They differ in brightness because of our distance from them as well as the brightness of the stars themselves. The farther a star is from us, the dimmer the star may be, despite the star being many times brighter than our Sun. The nearer a star is from us, the brighter the star may be, even if the star is actually dimmer than our sun.
First of all, I believe it is because of the differing energy within each and every star. The higher the energy, the brighter it is, and the lower the energy, the dimmer it appears. The distance of these stars to us is also a factor, where the farther the stars are, the dimmer they appear.
One thing that affects a star's brightness would probably be the distance you view it from. The further you are, the dimmer the star appears to be. Another thing that probably affects a star's brightness is the star's age.
Some stars may be near us and some stars are further away from us. Far away stars appear dimmer. Stars near to us appear brighter than far away stars.
Their proximity to us, how bright they burn, their color etc... There are a lot of reasons as to why stars' differ in brightness but these are the simplest answers. Some stars simply burn brighter than the others.
From what I understand, stars differ in brightness due to their distance from us. When an object is nearer, it may appear brighter, while a distant object will appear dimmer. Even if two stars have the same brightness, the star that is closer to the naked eye will appear brighter.

Table 3

Students' Responses on the Question "Why do stars appear to be changing positions in the sky?"

Questions: Why do stars appear to be changing positions in the sky?
This is both contributed by the fact that us, the Earth, and the stars, don't stay still. The whole solar system is moving towards the center of the Milky Way. The parallax effect causes us to view stars in different locations due to different points of view.
It has to do with the Earth's motion. Stars really stay in their place. However, they appear to be moving because of the Earth's rotation and revolution around the Sun.
It has to do with the Earth's motion. Stars really stay in their place. However, they appear to be moving because of the Earth's rotation and revolution around the Sun.
This happens due to parallax. When Earth moves around its orbit around the Sun, the farther stars will appear to move slower. This happens because farther objects look smaller, so they will also look slower.
The stars appear to be changing positions in the sky because of the Earth's rotation and its orbit around the Sun. The position of the observer changed because of the Earth's rotation and its orbit around the Sun. Due to this, the stars look like they changed their positions.
From what I understood from our classes, despite the stars appearing like they're changing positions, they actually aren't changing their positions at all. It's actually caused by us, the observers, who are changing positions which thus gives off the illusion that the stars are changing positions when they actually aren't. Basically, we as humans live on the planet Earth which is in constant motion revolving around the sun. It is because of this that our point of view changes when it comes to the stars, so to give an example, if we were to check out a star in a particular time then check on it after some time, it would have changed positions from our point of view because the Earth is in a different position and place in its orbit.
This is best described as the parallax effect as we view stars from a 2D perspective. The Earth slightly moves every day causing a different perspective of the stars in terms of relative position. For example, on one day, a star would appear on the left of another star, but several days later it shifts to the right. However, the stars aren't actually moving, it's actually caused by Earth's revolution. This can be clearly indicated from a 3D perspective that the stars are in constant position.
It is because the earth is revolving every year, which constantly makes the star move into different places.
This is because earth revolves around the sun and rotates around its own axis. The stars aren't moving, but we are, so our view of the night sky is constantly changing. Angles play a part in this too.
First of all, I believe that it is because of the orbit of the earth around the sun. The changing location of the earth makes the stars not appear in the same places as we saw them before. I also believe the rotation of the earth has to do with this.
Because Earth moves. Stars may remain stationary, but the Earth rotates and revolves around the sun. Because of that, stars appear to change positions.
The stars appear to be changing positions because of the Earth's rotation. The stars appear to be changing positions just like the sun. The stars appear to be moving because of the Earth's rotation.
Because of the movement of the earth. Because of the combination of the rotation of the Earth around its axis and the revolution of the sun around the Earth, different heavenly bodies. Rotation because of the slight inclination of the Earth and revolution because of the change in the Earth's position.
As I understand it, stars appear to move in the sky because of the Earth's orbit around the sun and around its own axis. As the Earth rotates or revolves, it changes its position relative to the planets and stars. The parts of the galaxy or universe appear in different positions since the Earth is constantly in motion.
Stars appear to be changing position because of parallax. As the Earth revolves around the sun, of course, our position changes. Because of this change in position, our perception changes, thus, the stars appear to be changing positions in the sky.

Correclation Analysis of Associationamong the Five SEMLIS Dimensions and Students' Final Grade in Earth Science

This section discusses the quantitative analysis of students' responses on Self-efficacy and Metacognition Learning Inventory in Science (SEMLIS), which was adapted from the work of Thomas et al. (2007). The instrument has a Cronbach's alpha value of .957 (Table 4).

Table 4

Descriptive Statistics and Cronbach's Alpha Coefficient of the Self-Efficacy and Metacognition Learning Inventory in Science (SEMLIS) Instrument

Mean	Variance	Std. Deviation	N	Cronbach's Alpha	Cronbach's Alpha based on Standardized Items
112.080	540.493	23.249	90	.957	.956

The SEMLIS instrument has five (5) dimensions: (1) *Constructivist Connectivity* (CC); (2) *Monitoring, Evaluation and Planning* (MEP); (3) *Self-Efficacy* (SE); (4) *Learning Risks Awareness* (AW); and (5) *Control of Concentration* (CO). The Constructivist Connectivity dimension contains items that analyze students' ability to build connections between information and what they know across various science learning locations. The *Monitoring, Evaluation and Planning* dimension contains items that may be related to metacognition. Such items reflect one's strategies to learn science, which may also be relevant to the learning of other subject areas. The *Self-Efficacy* dimension intend to analyze students' perceptions on their own ability to organize and make actions necessary to achieve science learning goals. Lastly, the *Control of Concentration* dimension can be related to students' monitoring and evaluation of their own learning.

Pearson product-moment correlation coefficient was used to analyze if there is any association between the students' final grade in Earth Science and each of the dimensions in SEMLIS. As shown in Table 5, some variables show statistically significant correlations. There were strong positive correlations between *Constructivist Connectivity and Monitoring, Evaluation and Planning* (r = .761), suggesting that students who demonstrate a high level of connectivity in constructing knowledge also tend to engage effectively in monitoring, evaluating, and planning their learning strategies. Similarly, significant positive correlations were found between Constructivist Connectivity and Self-Efficacy (r = .514), and Constructivist Connectivity and Control of Concentration (r = .676), indicating that students who exhibit strong connectivity in constructing knowledge also tend to possess higher levels of self-efficacy and better control over their concentration during the learning tasks. Additionally, the correlations between Monitoring, Evaluation and Planning, and Self-Efficacy (r = .582), as well as between Monitoring, Evaluation and Planning, and Control of Concentration (r = .806), further highlight the importance of effective planning and evaluation strategies in fostering self-efficacy and concentration levels.

These results show the importance of fostering active engagement in learning activities as a precursor to effective metacognitive regulation, which is a fundamental aspect of learning progression. Moreover, the active engagement and problem-solving tasks in the simulation activities have the potential to enhance students' metacognitive attributes and subsequently improve their academic performance.

Table 5

Pearson Product-Moment Correlation Coefficients

	Constructivist Connectivity	Monitoring, Evaluation & Planning	Self-Efficacy	Learning Risks Awareness	Control of Concentration	Final Grade
Constructivist Connectivity	1	0761**	0514**	0.355	.676**	0.24
Monitoring, Evaluation & Planning	.761**	1	.582**	.471**	.806**	-.060
Self-Efficacy	.514**	.582**	1	.176	.433*	.285
Learning Risks Awareness	.335	.471**	.176	1	.257	.098
Control of Concentration	.676**	.806**	.433*	.257	1	.060
Final Grade	.024	-.060	.285	.098	.060	1

Note. ** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

On the other hand, no significant correlations were observed between *Constructivist Connectivity* and *Learning Risks Awareness, Self-efficacy* and *Learning Risks Awareness,* as well as *Control of Concentration* and *Learning Risks Awareness.* This implies that the students' ability to construct knowledge and concentrate effectively does not necessarily influence their awareness of potential risks or challenges associated with their learning. Moreover, students may also feel confident in their abilities to learn and succeed without being fully aware of the risks they may encounter along the learning process.

Lastly, Table 5 also shows that there was no statistically significant correlation between students' final grade in Earth Science and each dimension in the SEMLIS instrument. This may indicate that variables such as self-efficacy, metacognition, and learning strategies, may not be the primary determinants of students' achievement in the said subject. As a result, educators and researchers may need to reconsider the significance of these factors in predicting students' final grades and academic achievements in the subject.

Students' Self-Efficacy and Metacognition

The utilization of simulation activities in education has been shown to have a profound impact on students' self-efficacy, primarily due to the autonomy it provides them in their learning process. Through these activities, students gain a sense of control over their learning trajectory, as evidenced by statements, such as *"I learn more", "I am able to",* and *"I can",* which indicate a growing confidence in their ability to comprehend and apply scientific concepts. This increased self-assurance serves as a foundation for students to pursue higher learning paths, as they believe in their capacity to tackle more complex subject matter. Furthermore, the positive correlation observed between *Constructivist Connectivity* and *Monitoring, Evaluation & Planning* validates students' ability to draw connections between information and scientific knowledge while strategizing their learning approach. This suggests that students are adept at integrating new information into their existing understanding and formulating effective learning strategies.

Moreover, the positive correlation between *Constructivist Connectivity* and *Self-Efficacy,* shows the students' ability to organize and execute plan of actions in attaining Science learning goals. On the other hand, the high correlation that exists between *Monitoring, Evaluation & Planning* and *Self-Efficacy* means that if a student perceives himself/herself as someone who has the capacity to perform specific tasks and make necessary plans, he/she can eventually learn how to do science.

For a student to have a successful and meaningful learning experience, *Monitoring, Evaluation & Planning* plays a significant role to have a strong *Control of Concentration.* As previously mentioned, students struggle to maintain their focus in learning. Strategizing how to learn may help them enhance their concentration while learning. Having the ability to identify factors that may be detrimental to one's learning can also facilitate a good control of concentration.

Conclusion and Recommendations

Based on students' perceptions on their learning experiences, the use of simulations provided them with immersive and interactive experiences. As these activities foster active participation and hands-on exploration, students became directly involved in the scientific process. In the qualitative data analysis, students responded positively when they described their learning experience. Their responses reflect their understanding of earth science topics through the simulation activities.

The simulation activities not only enhance understanding but also cultivates critical thinking and problem-solving skills. One student cited that the activity helped them to clearly understand reasons why eclipses do not occur every month. Such responses demonstrate their own understanding of astronomical events, and this corroborates with students' high scores in the *Constructivist Connectivity* component of the SEMLIS instrument. These are qualifying evidence of attaining higher level in the hierarchy of hypothetical learning progression.

Based on the findings, the use of simulations in teaching Earth Science enhances learning progression by providing students with engaging and interactive learning experiences that promote deeper understanding and skill development. Tracking students' interactions and performances can help educators gain valuable insights into how student learning progresses and adapt instruction to meet each student's needs. Furthermore, simulations play a crucial role in fostering students' self-efficacy by providing them with opportunities for autonomy and mastery in the learning process. As such, the integration of simulations in science education holds promise for improving learning outcomes and empowering students to become confident and competent problem-solvers in the field of science.

The absence of a correlation between students' final grade in Earth Science and each dimension measured by the SEMLIS instrument may prompt educators to explore alternative explanations for students' academic performance in Earth Science. It suggests that other factors not captured by the SEMLIS instrument, (e.g. prior knowledge, interest in the subject, teaching quality, and cultural and environmental influences), may play a more significant role in shaping students' outcomes. Therefore, educators may need to adopt a more holistic approach to understanding student learning and academic achievement, considering a broader range of factors that could impact students' performance in Earth Science. This could involve improving the intervention done in this study, incorporating additional assessment tools, conducting interviews and qualitative inquiries, or examining contextual factors within the learning environment to gain deeper insights into students' learning experiences and outcomes. Further, it is also recommended to apply the integration of hypothetical learning progression and simulations and make a comparison of students' performance during face-to-face classes and online classes.

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