

Enhancing Grade 11 Students' Conceptual Understanding of Geological Processes and Earth's Internal Heat through the Design Thinking Process

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ABSTRACT

This study investigated the effectiveness of the Design Thinking Process (DTP) in enhancing Grade 11 students' conceptual understanding of geological processes and Earth's internal heat and explored their experiences during its implementation. An explanatory sequential mixed-methods design was employed with 48 Grade 11 General Academic Strand students from two intact sections. Twenty-four students received instruction through DTP, while 24 students were taught using a traditional lecture-based approach. Quantitative data were collected using a validated 30-item conceptual understanding test administered before and after the intervention. Qualitative data were obtained through semi-structured interviews with 12 students from the experimental group. Results showed that both groups improved following instruction, but the DTP group obtained a higher mean gain (7.50) than the control group (3.58). The difference in learning gains was statistically significant, $t = 4.20$, $p < .001$. The DTP group also achieved a significantly higher posttest mean (23.54) than the control group (19.46), $t = -3.409$, $p = .001$. The qualitative findings generated five themes: (1) adjusting emotionally to learning geological processes through a student-centered approach; (2) reconstructing the meaning of learning science through actively constructing knowledge; (3) deepening conceptual understanding of Earth's internal heat and geological processes through experiential engagement; (4) developing collaborative and scientific problem-solving competence through negotiating and teamwork; and (5) experiencing contextual challenges while recognizing the long-term scientific value of DTP. These findings indicate that DTP supported not only conceptual learning but also active knowledge construction, learner independence, experiential engagement, collaboration, and problem-solving. However, students also experienced challenges related to emotional adjustment, time management, workload, and group participation. The study concludes that DTP is a promising student-centered approach for teaching complex Earth Science concepts when supported by adequate time allocation, teacher scaffolding, clear expectations, and structured collaborative activities.

Keywords: Design Thinking Process, Earth Science, experiential learning, geological processes, inquiry-based learning, science learning

INTRODUCTION

Science education plays a vital role in developing learners' scientific literacy, critical thinking, and problem-solving skills necessary for understanding real-world phenomena and addressing contemporary global challenges. In the 21st century, science instruction is expected not only to promote factual knowledge but also to cultivate inquiry, creativity, collaboration, and conceptual understanding among learners. However, many educational systems continue to struggle to achieve meaningful science learning outcomes, particularly in areas involving abstract and interdisciplinary scientific concepts. These challenges have increased the demand for innovative, student-centered, and experiential instructional approaches that actively engage learners in constructing and applying scientific knowledge.

Science education in the Philippines continues to face major challenges, particularly in students' conceptual understanding and academic performance. Results from the Programme for International Student Assessment (PISA) consistently revealed low science performance among Filipino learners. In the 2018 PISA, the Philippines ranked second to the lowest among 79 participating countries with an average science score of 357, while the 2022 PISA results showed no significant improvement, with the country ranking third lowest among 81 nations and obtaining an average score of 356 in science, far below the Organization for Economic Co-operation and Development (OECD) average (Landicho, 2021; Acido et al., 2024). These findings highlight persistent issues in science instruction, student engagement, and conceptual understanding, emphasizing the need for innovative and learner-centered instructional approaches.

One area in science that presents substantial learning difficulties is Earth Science, particularly concepts related to geological processes and Earth's internal heat. Earth Science is interdisciplinary, integrating concepts from physics, chemistry, biology, and environmental science to explain natural phenomena and Earth systems (Jaeger et al., 2017). However, students often struggle with abstract scientific concepts due to limited opportunities for hands-on learning, overreliance on memorization, and insufficient inquiry-based activities (Cooper & Berry, 2020). Topics such as magma formation, metamorphism, plate tectonics, and Earth's internal heat are particularly difficult because they involve abstract subsurface processes that cannot be directly observed.

These difficulties are likewise evident in local educational contexts. Based on school assessment records from Wright National High School (WNHS), Grade 11 General Academic Strand (GAS) students consistently obtained Mean Percentage Scores below the 75% proficiency benchmark in Earth and Life Science over the past three academic years. Least Learned Competency reports further revealed that competencies related to Earth's internal heat and geological processes were among the most difficult topics for students. According to Earth and Life Science teachers, these concepts are challenging because they are abstract, broad, and difficult to visualize within limited classroom time and available instructional resources.

Traditional lecture-based instruction may be insufficient in addressing these conceptual difficulties because it often limits student engagement, inquiry, and active participation. Recent educational literature emphasizes the importance of student-centered and experiential approaches that promote critical thinking, collaboration, and problem-solving skills (Novawan, 2024). One instructional approach that has gained attention is the Design Thinking Process (DTP). This human-centered and iterative framework encourages learners to empathize, define problems, ideate, prototype, and test solutions (Dam & Siang, 2021). Through hands-on and inquiry-based activities, DTP enables learners to actively construct knowledge and connect scientific concepts to meaningful learning experiences.

The educational foundation of Design Thinking is closely associated with experiential and constructivist learning theories. Kolb's Experiential Learning Theory explains that meaningful learning occurs through concrete experiences, reflection, conceptualization, and active experimentation (Kolb, 1984). Similarly, Piaget's Constructivist Learning Theory emphasizes that learners actively build understanding through exploration, interaction, and adaptation. The Design Thinking Process aligns with these perspectives by engaging students in collaborative inquiry, creative problem-solving, and reflective learning activities that support deeper conceptual understanding. The theoretical relationships guiding the study are presented in Figure 1.

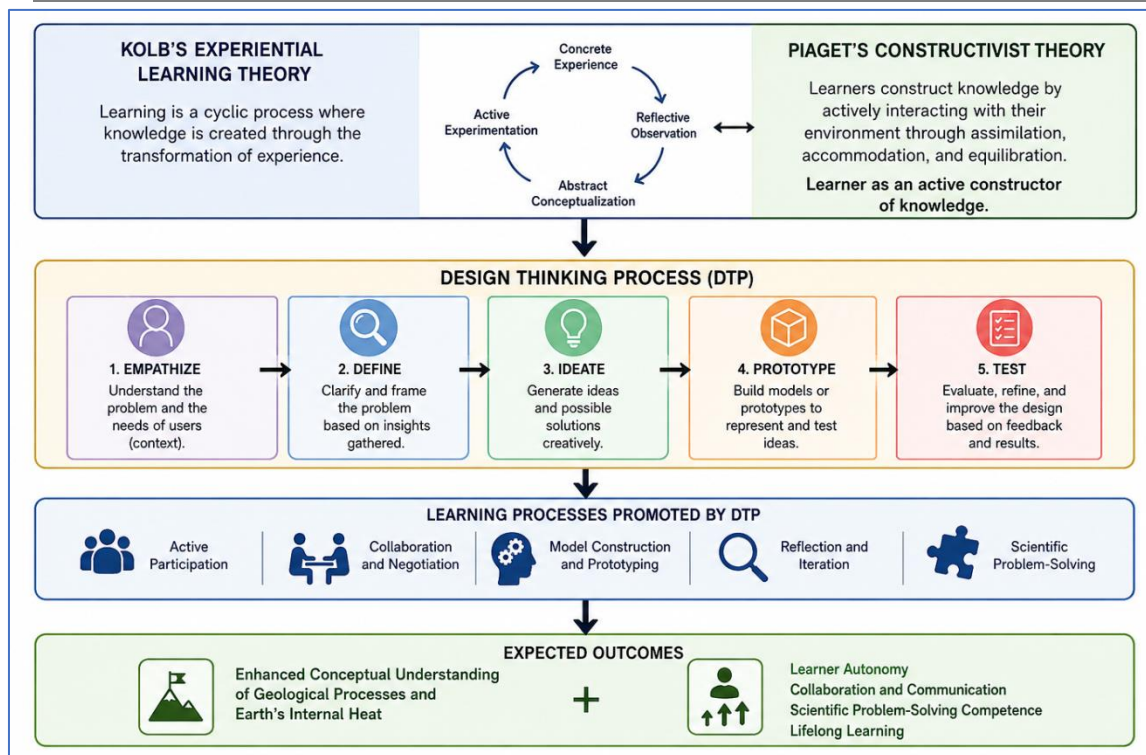


Figure 1. Conceptual Framework Linking Kolb's Experiential Learning Theory, Piaget's Constructivist Learning Theory, and the Design Thinking Process

Despite its growing application in other educational fields, the Design Thinking Process remains underutilized in science education, particularly in Earth Science instruction. Many classrooms continue to rely heavily on teacher-centered approaches that may not adequately support conceptual understanding of complex and abstract scientific phenomena. This highlights the need to explore more innovative and student-centered strategies that can improve both engagement and learning outcomes in science education.

Hence, this study investigated the effectiveness of the Design Thinking Process in enhancing Grade 11 students' conceptual understanding of geological processes and Earth's internal heat. Specifically, the study examined the differences between students exposed to the Design Thinking Process and those taught using the traditional lecture-based method. The study also explored students' experiences and challenges in utilizing the Design Thinking Process and developed an enhanced lesson plan integrating DTP for Earth Science instruction. The findings of the study may provide valuable insights for educators, curriculum developers, and school administrators in strengthening instructional practices and improving conceptual learning in science education.

METHODS

Research Design

This study employed a mixed-methods approach using an explanatory sequential design to investigate the effectiveness of the Design Thinking Process (DTP) in enhancing Grade 11 students' conceptual understanding of geological processes and Earth's internal heat. In this design, quantitative data were collected and analyzed first, followed by qualitative inquiry to further explain and enrich the quantitative findings. This approach provided a comprehensive understanding of both students' learning outcomes and their experiences during the implementation of the Design Thinking Process.

The quantitative phase utilized a quasi-experimental nonequivalent groups design involving two intact Grade 11 General Academic Strand (GAS) sections. One section served as the experimental group and received instruction using the Design Thinking Process, while the control group was taught using the conventional lecture-based method. Pretest and posttest assessments were administered to both groups to determine changes in students' conceptual understanding of geological processes and Earth's internal heat. Baseline comparability between

groups was established through the school's balanced sectioning procedure and verification using pretest mean score comparisons.

The qualitative phase was conducted to provide deeper insights into students' learning experiences during the implementation of the Design Thinking Process. Twelve students from the experimental group participated in semi-structured interviews and reflective activities. Participants were selected based on the principle of data saturation to ensure comprehensive representation of experiences and perceptions regarding the Design Thinking Process.

The integration of quantitative and qualitative findings allowed the study to explain not only whether the Design Thinking Process improved conceptual understanding but also how students experienced and interpreted the learning process throughout the intervention.

Research Locale and Participants

The study was conducted in a public secondary school in Wright I District, Paranas, Samar, Philippines, during the Academic Year 2025–2026. The school offers Senior High School education under the K to 12 curriculum and maintains two Grade 11 General Academic Strand (GAS) sections annually.

The participants of the study consisted of 48 Grade 11 students enrolled in two intact GAS sections. Twenty-four students were assigned to the experimental group, while 24 students comprised the control group. The sections were selected purposively based on comparable academic characteristics and heterogeneous composition. Group assignment as experimental or control was determined through a simple coin toss to minimize researcher bias.

For the qualitative phase, 12 students from the experimental group were purposively selected to participate in semi-structured interviews and reflective activities. Selection continued until thematic saturation was achieved.

Research Instruments

Conceptual Understanding Test. The primary quantitative instrument was a researcher-developed 30-item multiple-choice test administered as both pretest and posttest. The instrument was designed to assess students' conceptual understanding of geological processes and Earth's internal heat based on the Grade 11 Earth and Life Science curriculum and the Most Essential Learning Competencies (MELCs). The test covered concepts related to Earth's internal heat, magma formation, rock formation, plate tectonics, and landform development.

A Table of Specifications (TOS) was developed to ensure alignment between test items, learning competencies, and cognitive domains based on Bloom's Taxonomy. Several items were adapted from the school's validated Test Item Data Bank to ensure content relevance and appropriate difficulty level.

Interview Guide. To complement the quantitative findings, a semi-structured interview guide was utilized during the qualitative phase. The instrument explored students' experiences, engagement, conceptual understanding, and challenges encountered while using the Design Thinking Process in learning Earth Science concepts.

Validation and Reliability of Instruments

The research instruments underwent content validation by a panel consisting of the research adviser and two science education specialists. The validators examined the instruments for content accuracy, clarity, alignment with curriculum competencies, and suitability for Grade 11 learners. Necessary revisions were incorporated based on their recommendations.

Pilot testing was conducted among 20 Grade 11 students from non-participating sections to determine the reliability and appropriateness of the test items. Item analysis was subsequently performed, leading to the reduction of the original 50-item test into a refined 30-item instrument.

The reliability of the instrument was established through test–retest reliability analysis, yielding a reliability coefficient of 0.801, indicating acceptable reliability for educational research.

Data Gathering Procedure

Before data collection, ethical clearance and institutional permissions were secured from the appropriate authorities. Informed consent from parents or guardians and assent from student participants were obtained before the study was conducted.

The quantitative phase began with the administration of the pretest to both groups to determine baseline conceptual understanding. Following the pretest, the experimental group received instruction using the Design Thinking Process, while the control group underwent conventional lecture-based instruction. The intervention lasted for fifteen instructional days from July 21 to August 8, 2025. After the intervention, both groups completed the posttest.

After the quantitative phase, semi-structured interviews were conducted with selected students from the experimental group to explore their experiences and challenges during the implementation of the Design Thinking Process. Interviews were audio-recorded, transcribed, and analyzed for thematic patterns.

Data Analysis

Quantitative data were analyzed using descriptive and inferential statistical techniques. Mean and standard deviation were used to describe students' pretest and posttest performance. The Shapiro–Wilk test was utilized to determine the normality of data distribution. Paired-sample t-tests were used to determine significant differences between pretest and posttest scores within groups. In contrast, independent-sample t-tests were utilized to compare posttest scores between the experimental and control groups.

Qualitative data obtained from the semi-structured interviews were analyzed following Braun and Clarke's (2006) thematic analysis framework. The analysis involved data familiarization, coding, theme identification, theme development, and refinement to identify recurring patterns related to students' experiences, engagement, and conceptual understanding during the Design Thinking Process intervention.

Ethical Considerations

Ethical standards were strictly observed throughout the conduct of the study. Ethical clearance was secured from the Samar State University Institutional Human Research Ethics Committee (IHREC Code: 2025-0067-G). Permission to conduct the study was likewise obtained from the Schools Division Superintendent and the participating school administration.

Participation in the study was voluntary. Informed consent from parents or legal guardians and assent from student participants were secured before data collection. Participants were informed about the purpose of the study, the voluntary nature of participation, and their right to withdraw at any time without penalty.

Confidentiality and anonymity were maintained through the use of pseudonyms and coded identifiers. All collected data were securely stored and used solely for research purposes. To ensure fairness, Design Thinking-based learning activities were also made available to the control group after the completion of the study.

RESULTS AND DISCUSSION

Students' Conceptual Understanding of Geological Processes and Earth's Internal Heat

This section presents the quantitative findings on students' conceptual understanding of geological processes and Earth's internal heat after exposure to the traditional teaching method and the Design Thinking Process (DTP). The analysis focused on comparing the pretest and posttest performances of the control and experimental groups to determine the effectiveness of the intervention.

Table 1 Pretest and Posttest Mean Scores of the Control and Experimental Groups

Group	Pretest Mean	Posttest Mean	Mean Gain	Interpretation
Control Group (Traditional Method)	15.83	19.46	3.58	Nearly Proficient
Experimental Group (Design Thinking Process)	16.04	23.54	7.50	Proficient

The results indicate that both groups improved after instruction; however, the experimental group exposed to the Design Thinking Process demonstrated substantially higher learning gains compared to the control group taught using the traditional method. Before the intervention, both groups exhibited relatively comparable levels of conceptual understanding, suggesting baseline equivalence between the groups. The control group obtained a pretest mean score of 15.83, interpreted as Nearly Proficient, while the experimental group achieved a pretest mean score of 16.04, interpreted as Nearly Proficient.

Following the intervention, both groups demonstrated improvement in posttest performance. The control group obtained a posttest mean score of 19.46 with a mean gain of 3.58, while the experimental group achieved a higher posttest mean score of 23.54 with a mean gain of 7.50. The experimental group also attained a Proficient level of conceptual understanding, indicating stronger mastery of concepts related to geological processes and Earth's internal heat.

The findings suggest that the Design Thinking Process was more effective in enhancing students' conceptual understanding compared to the traditional lecture-based approach. The substantial increase in the experimental group's performance may be attributed to the inquiry-based, collaborative, and experiential nature of the Design Thinking Process, which enabled students to actively construct knowledge, visualize abstract concepts, and engage in authentic problem-solving activities. Through activities such as brainstorming, model construction, prototyping, and testing, students were able to connect theoretical Earth Science concepts with meaningful learning experiences.

The findings support previous studies emphasizing the effectiveness of experiential and design-based learning approaches in science education. Ladachart et al. (2022) explained that design-based learning enhances conceptual understanding by promoting active engagement and knowledge construction. Similarly, Henriksen et al. (2017) emphasized that Design Thinking strengthens higher-order thinking and conceptual learning through collaborative inquiry and creative problem-solving activities. These findings indicate that active and student-centered instructional strategies may be more effective than traditional lecture-based instruction in improving conceptual understanding of complex and abstract Earth Science concepts.

Comparison of the Pretest–Posttest Mean Difference Scores of the Two Groups

To determine whether a significant difference existed between the learning gains of the control and experimental groups, the pretest–posttest mean difference scores were compared using an independent-samples t-test.

Table 2 Comparison of the Pretest–Posttest Mean Difference Scores of the Two Groups

Group	Mean Gain	Mean Difference Between Groups	t-value	p-value	Interpretation
Control Group	3.58	3.92	4.20	< .001	Significant
Experimental Group	7.50				

The table shows that the experimental group obtained a substantially higher mean gain score (7.50) compared to the control group (3.58). The computed mean difference between the two groups was 3.92, with a t-value of 4.20 and a p-value of less than .001. Since the p-value was lower than the 0.05 level of significance, the null

hypothesis was rejected, indicating a statistically significant difference between the learning gains of the two groups.

The findings indicate that the Design Thinking Process significantly enhanced students' conceptual understanding of geological processes and Earth's internal heat compared to the traditional instructional approach. The significantly higher gain score of the experimental group suggests that experiential and inquiry-based learning activities facilitated deeper conceptual engagement and more meaningful learning experiences among students.

The results support previous studies emphasizing the effectiveness of active learning approaches in science education. Ballen et al. (2017) reported that student-centered instructional strategies significantly improve conceptual understanding and academic achievement compared to traditional lecture-based instruction. Similarly, Boller and Mendaño (2024) emphasized that inquiry-driven and problem-centered approaches promote meaningful scientific learning by engaging students in authentic problem-solving activities.

The findings therefore suggest that integrating the Design Thinking Process into Earth Science instruction may lead to stronger conceptual understanding, increased engagement, and improved learning outcomes among students.

Comparison of the Posttest Mean Scores of the Two Groups

To further determine the effectiveness of the intervention, the posttest mean scores of the control and experimental groups were compared after the implementation of the instructional treatments.

Table 3 Comparison of the Posttest Mean Scores of the Two Groups

Group	n	Posttest Mean	t-value	p-value	Interpretation
Control Group (Traditional Method)	24	19.46	-3.409	0.001	Significant
Experimental Group (Design Thinking Process)	24	23.54			

The table reveals that the experimental group obtained a higher posttest mean score of 23.54 compared to the control group's posttest mean score of 19.46. Statistical analysis showed a t-value of -3.409 and a p-value of 0.001 , indicating a statistically significant difference between the posttest performances of the two groups at the 0.05 level of significance. Since the computed p-value was lower than 0.05 , the null hypothesis was rejected.

The findings indicate that the Design Thinking Process was more effective than the traditional teaching method in improving students' conceptual understanding of geological processes and Earth's internal heat. The higher posttest performance of the experimental group may be attributed to the active, collaborative, and inquiry-based learning experiences embedded in the Design Thinking Process. Through brainstorming, prototyping, model construction, testing, and reflection, students were encouraged to actively engage in scientific inquiry and apply concepts in meaningful contexts.

The findings are consistent with Fitriyah et al. (2025), who reported that Design Thinking and problem-based learning approaches significantly improve students' conceptual understanding and higher-order thinking skills in science education. Similarly, experiential and collaborative instructional strategies have been found to strengthen conceptual learning by allowing students to connect abstract scientific ideas with authentic and observable experiences.

The results therefore imply that instructional strategies significantly influence students' conceptual understanding and academic performance. Integrating the Design Thinking Process into Earth Science instruction may provide a more effective approach for enhancing conceptual learning, critical thinking, and scientific reasoning compared to conventional lecture-based instruction.

Challenges of Grade 11 Students in the Utilization of the Design Thinking

Process (DTP)

The qualitative analysis generated five themes that describe students' experiences, perceived benefits, and challenges during the implementation of the Design Thinking Process. The themes reflect students' emotional adjustment, active construction of knowledge, experiential engagement, collaborative problem-solving, and recognition of the contextual demands and longer-term value of DTP. A summary of the themes and their central meanings is presented in Table 4.

Table 4 Summary of Students' Experiences in the Design Thinking Process

Theme	Central Finding	Educational Implication
1. Adjusting Emotionally to Learning Geological Processes Through a Student-Centered Approach	Students initially experienced nervousness, confusion, and pressure but gradually developed fulfillment and confidence.	Provide orientation, scaffolding, and teacher support during initial DTP activities.
2. Reconstructing the Meaning of Learning Science Through Actively Constructing Knowledge	Students shifted from listening and memorization toward active participation, independent learning, and knowledge construction.	Provide opportunities for inquiry, independent learning, and active knowledge construction.
3. Deepening Conceptual Understanding of Earth's Internal Heat and Geological Processes Through Experiential Engagement	Model construction, prototyping, exploration, and self-discovery helped students understand abstract geological concepts.	Integrate models, prototypes, and hands-on activities when teaching abstract Earth Science concepts.
4. Developing Collaborative and Scientific Problem-Solving Competence Through Negotiating and Teamwork	Students developed cooperation, communication, negotiation, and problem-solving skills while also experiencing misunderstandings and unequal participation.	Establish clear group roles and monitor equitable participation.
5. Experiencing Contextual Challenges While Recognizing the Long-Term Scientific Value of DTP	Time constraints and competing academic demands were challenging, but students recognized the relevance and value of DTP.	Provide sufficient time, clear expectations, and appropriate teacher scaffolding.

Theme 1: Adjusting Emotionally to Learning Geological Processes Through a Student-Centered Approach

Students' lived experiences in utilizing the Design Thinking Process (DTP) revealed a significant emotional adjustment as they engaged in learning geological processes through a student-centered approach. The transition from a familiar teacher-led classroom structure to a more participatory and autonomous learning environment initially generated strong emotional reactions, which gradually evolved as students continued engaging in the process.

Vignettes:

"I feel nervous because I know that the Design Thinking Process is challenging and student-centered in the Teaching and Learning process." (Participant 1)

"I feel so confused because first of all I don't know this process and why this is called Design Thinking Process." (Participant 3)

“Well my initial reactions is that I’m shock like literally. Thinking it was going to be a challenge I wouldn’t handle, and also the fact that I’m not prepared.” (Participant 8)

“At first, trying DTP was hard and made me feel pressured since it is student-centered, which means we, students, must learn things on our own.” (Participant 9)

“It was stressful at first but worth it in the end.” (Participant 2)

“It was exhausting but fulfilling.” (Participant 11)

“Seeing our finished model made me feel fulfilled.” (Participant 6)

These responses show that students initially found DTP challenging because it differed from their usual classroom experience. Their feelings of nervousness, confusion, and pressure suggest that they needed to adjust to greater autonomy, participation, and responsibility for learning. This is consistent with Aflatoony et al. (2018), who found that students in a secondary-level Design Thinking course had to adapt to new forms of collaborative problem-solving and design practice.

The emotional responses observed in the present study also reflect the affective demands associated with design-based learning. Students may experience uncertainty, stress, and other emotional responses when engaging in unfamiliar, open-ended tasks that require active participation and decision-making (Zhang et al., 2020). In the present study, these emotions appeared most strongly during the initial stages of the intervention, when students were still becoming familiar with the DTP process and their increased responsibility for learning.

As the intervention progressed, however, students reported more positive experiences. Participants described DTP as “stressful at first but worth it in the end” (P2) and “exhausting but fulfilling” (P11), while Participant 6 stated, “Seeing our finished model made me feel fulfilled.” These accounts indicate a shift from initial discomfort to a sense of accomplishment as students completed the design activities. The completion of tangible outputs, particularly the models they developed, appeared to provide students with visible evidence of their effort and progress.

Taken together, the findings suggest that the initial emotional challenges were part of students' adjustment to a more autonomous and collaborative learning environment rather than an indication of disengagement. As students became more familiar with the process and completed the design tasks, their initial negative reactions were accompanied by feelings of fulfillment and accomplishment. This suggests that implementing DTP in Earth Science may require sufficient orientation, scaffolding, and teacher facilitation during the early stages to help students manage the demands of a student-centered learning environment.

Theme 2: Reconstructing the Meaning of Learning Science Through Actively Constructing Knowledge

Several participants described how their understanding of learning science fundamentally changed as they engaged in the Design Thinking Process. Rather than perceiving learning as a passive activity centered on listening and memorization, students began to view it as an active, participatory, and meaning-making process that required effort, engagement, and ownership.

Vignettes:

“Learning is not just listening but doing.” (Participant 6)

“It changed how I view learning. I became more independent in doing my tasks.” (Participant 1)

“We are not just memorizing but understanding.” (Participant 6)

“This method makes learning more meaningful.” (Participant 12)

“It helped me not to rely too much on my teacher.” (Participant 4)

"I learned to study and research on my own." (Participant 7)

These responses indicate a shift from passive reception of information toward active participation and knowledge construction. Students began to recognize that learning required them to explore, investigate, and apply ideas rather than receive information from the teacher. This interpretation is consistent with Hilvano and Mendaño (2026), whose meta-analysis showed that active learning approaches generally produce better student performance than traditional lecture-based instruction in STEM education.

The students also reported greater independence in learning. Their reduced reliance on the teacher and increased willingness to study and research on their own suggest the development of learner autonomy. This is consistent with studies showing that student-centered learning environments can provide learners with greater opportunities to take responsibility for their learning and make decisions during learning activities (Mäkitalo, 2016).

The change was also reflected in students' descriptions of learning as more meaningful. The statements "Learning is not just listening but doing" and "We are not just memorizing but understanding" suggest that students associated meaningful learning with active engagement rather than simple recall. Through DTP activities, students were required to investigate problems, develop ideas, construct models, and make decisions, allowing them to apply scientific concepts in the process.

The findings suggest that DTP influenced not only students' understanding of science concepts but also their perception of how learning takes place. The shift from listening and memorizing toward doing, understanding, and independent study indicates greater learner agency. Thus, DTP provided students with opportunities to become more active and responsible participants in the learning process.

Theme 3: Deepening Conceptual Understanding of Earth's Internal Heat and Geological Processes Through Experiential Engagement

Students' lived experiences in the Design Thinking Process (DTP) revealed that experiential engagement significantly deepened their conceptual understanding of Earth's internal heat and related geological processes. Through hands-on exploration, model construction, and idea development, students moved beyond surface-level comprehension toward a more integrated and applied understanding of scientific concepts.

Several participants described how their understanding improved through active participation in the learning tasks:

"It helps me understand the lesson more deeply. I discovered that I can be creative." (Participant 6)

"We explore new information and new learnings while making our model." (Participant 3)

"It improves my understanding because we discover ideas by ourselves." (Participant 11)

"Prototype phase because we can apply what we learned into a model." (Participant 4)

"The prototype phase is the most meaningful for me because we can see the output of our ideas." (Participant 7)

Across these responses, students emphasized exploration, self-discovery, and the application of knowledge. Their statements suggest that understanding was developed through active involvement rather than through direct transmission of information. The process of researching, discussing, designing, and constructing models allowed students to work with scientific ideas while developing representations of geological processes.

This finding is consistent with Pugh et al. (2017), who reported that design-based learning can support the development of students' scientific understanding through active engagement in designing, exploring, and revising ideas. The present findings similarly suggest that students gained a deeper understanding when they were required to use scientific concepts while completing meaningful design tasks.

The prototype phase appeared particularly important because it allowed students to transform abstract ideas into tangible representations. This is relevant to Earth Science concepts such as Earth's internal heat and geological processes, which involve mechanisms that cannot be directly observed. In the present study, students' emphasis on model construction and prototyping suggests that physical representations helped them visualize and apply concepts that might otherwise remain abstract.

The students also associated this process with greater personal engagement. Participant 6's statement that "I discovered that I can be creative" indicates that conceptual learning was accompanied by recognition of their own capacity to generate and develop ideas. Creativity therefore became part of the learning process rather than a separate outcome.

Overall, the findings suggest that experiential engagement through DTP helped students move beyond receiving scientific information toward exploring, applying, and representing scientific concepts. The combination of hands-on activities, model construction, and self-directed exploration appeared to make complex geological concepts more concrete and meaningful to the learners.

Theme 4: Developing Collaborative and Scientific Problem-Solving Competence Through Negotiating and Teamwork

Students' lived experiences in the Design Thinking Process (DTP) revealed that collaboration was both a challenge and a developmental opportunity. Engaging in group-based tasks required students to negotiate ideas, manage differences, and work collectively toward constructing meaningful scientific models. Through this process, they developed not only collaborative skills but also competencies in scientific problem-solving.

Several participants described their experiences working within their groups:

"We share our thoughts and ideas to create a better model. We learned to adjust and cooperate." (Participant 2)

"Sometimes we have misunderstandings in our group." (Participant 3)

"Communication is challenging because not everyone participates equally." "I learned to respect different opinions." (Participant 12)

These responses show that collaboration involved both challenges and opportunities for learning. Students recognized the need to share ideas and make decisions together (P2), while misunderstandings and unequal participation created communication difficulties (P3, P12). Through these experiences, students learned to adjust, cooperate, and respect different perspectives.

The findings are consistent with Maneewan et al. (2024), who found that Design Thinking-based science activities can develop teamwork, communication, collaboration, and problem-solving skills. Similarly, Hoa (2025) reported that integrating Design Thinking into high school STEM learning can strengthen students' problem-solving and critical-thinking skills. In the present study, students practiced these competencies by negotiating ideas, evaluating possible solutions, and making group decisions while developing their models.

The challenges encountered during group work therefore became part of the learning process. Students learned that developing a satisfactory model required communication, cooperation, and consideration of different ideas. These experiences also provided opportunities to practice problem-solving through the discussion, evaluation, and refinement of possible solutions.

Thus, DTP supported the development of collaborative and problem-solving competencies. However, the reported misunderstandings and unequal participation suggest that effective implementation requires clear group roles and appropriate teacher facilitation to ensure meaningful participation among students.

Theme 5: Experiencing Contextual Challenges While Recognizing the Long-Term Scientific Value of DTP

Students' lived experiences in the Design Thinking Process (DTP) revealed that while the implementation presented contextual and academic challenges, they simultaneously recognized its long-term value for their personal and academic development. The demands of time management and workload pressures were balanced by their appreciation of the process as meaningful, supportive, and beneficial for future learning.

Several participants described these experiences:

"Time management was hard because we need to finish the model on time." (Participant 2)

"We had difficulty managing our time, especially when all subjects have activities." (Participant 5)

"The teacher guided us properly in every stage of the process." (Participant 1)

"It trains us for real-life problem solving." (Participant 6)

"I think this will help me in college." (Participant 8)

"I would recommend this to other students because it is fun and meaningful." (Participant 1)

Across these responses, students identified time management and competing academic requirements as the main challenges in using DTP (P2, P5). Completing the models within the given time required them to balance DTP activities with other school requirements. This shows that project-based learning can place additional demands on students' time and responsibilities.

Teacher guidance also helped students manage these demands. Participant 1 stated, "The teacher guided us properly in every stage of the process." This indicates that while DTP promoted student responsibility, teacher support remained important in providing direction and structure throughout the activities.

Despite these challenges, students recognized the broader value of DTP. Participant 6 stated, "It trains us for real-life problem solving," while Participant 8 noted, "I think this will help me in college." These responses suggest that students saw the skills developed through DTP as useful beyond the classroom. This finding is consistent with Ladachart et al. (2022), who found that design-based learning provides opportunities for students to apply scientific knowledge through authentic design and problem-solving activities.

Students also viewed the experience positively. Participant 1 described DTP as "fun and meaningful," indicating that the benefits of the approach outweighed the difficulties they experienced. The combination of active participation, teacher support, and practical application may have contributed to this positive perception.

Students experienced DTP as challenging but worthwhile. While time constraints and competing academic demands created difficulties, teacher guidance helped students manage the process, and the perceived relevance of the skills increased its value. These findings suggest that effective DTP implementation requires sufficient time, clear instructions, and appropriate teacher support.

CONCLUSION AND RECOMMENDATIONS

The findings demonstrate that the Design Thinking Process (DTP) is a promising instructional approach for enhancing Grade 11 students' conceptual understanding of geological processes and Earth's internal heat. Although both groups improved following instruction, students exposed to DTP achieved substantially greater learning gains and significantly higher posttest performance than those who received traditional instruction. The quantitative findings suggest that the active, experiential, and design-based nature of DTP can provide effective opportunities for students to engage with complex and abstract Earth Science concepts.

The qualitative findings further explain the learning experiences underlying these outcomes. Students initially experienced nervousness, confusion, pressure, and difficulty adjusting to a more student-centered learning

environment. As they became familiar with the process, however, they reported greater independence, active participation, and fulfillment. Their experiences also showed that model construction and prototyping helped them explore and apply scientific ideas, while group activities provided opportunities to develop communication, cooperation, negotiation, and problem-solving skills. Although time constraints, competing academic requirements, and unequal participation presented challenges, students generally perceived the experience as meaningful and relevant to future academic and real-life situations.

Taken together, the quantitative and qualitative findings indicate that DTP can support both conceptual learning and the development of learner-centered competencies in Earth Science. The approach appears particularly useful for concepts that are abstract or difficult to observe directly because students can represent, apply, and refine scientific ideas through models and prototypes. However, the findings also indicate that DTP should not be implemented without adequate structure. Teachers should provide clear orientation, realistic time allocation, appropriate scaffolding, and well-defined group roles to help students manage the demands of the process. The integration of DTP into Earth Science instruction may therefore be considered as a complementary strategy for promoting conceptual understanding, learner autonomy, collaboration, and scientific problem-solving.

The findings suggest that DTP may be integrated into Earth Science instruction, particularly for competencies involving abstract and difficult-to-visualize geological processes. Science teachers may incorporate structured model construction, prototyping, testing, and reflection activities while providing clear instructions, realistic timelines, and appropriate scaffolding. Given the students' reported difficulties with time management and unequal participation, teachers should establish clear group roles, monitor participation, and provide guidance during the initial stages of the process. At the school and division levels, professional learning activities may be provided to strengthen teachers' capacity to design and facilitate DTP-based and inquiry-oriented science lessons. Schools may also support the development and use of low-cost instructional materials for modeling and prototyping so that DTP can be implemented within typical public-school resource constraints. These measures may help teachers integrate DTP without compromising curriculum pacing and other academic requirements.

Limitations of the Study

Several limitations should be considered when interpreting the findings. First, the study involved only 48 Grade 11 students from two intact sections in one public secondary school in Paranas, Samar; therefore, the findings may not be generalizable to students in other grade levels, schools, or contexts. Second, the quasi-experimental design used intact classes, which limits the ability to establish causal relationships despite the use of pretest and posttest measures. Third, the intervention lasted for only 15 instructional days, which limits conclusions regarding the long-term retention and transfer of conceptual understanding. Fourth, the qualitative findings were based on interviews with 12 students from the experimental group and therefore represent experiences within the specific intervention context. Finally, the study focused on selected concepts related to geological processes and Earth's internal heat; consequently, the findings should not be generalized to all Earth Science competencies.

Future research may further examine the effectiveness of DTP using larger and more diverse samples, different Earth Science topics, and longer intervention periods. Studies may also investigate the retention and transfer of conceptual understanding to determine whether the learning gains associated with DTP are sustained over time and applied to unfamiliar scientific contexts. Such investigations would provide further evidence on the conditions under which Design Thinking can be effectively integrated into science education.

REFERENCES

1. Acido, J. V., & Caballes, D. G. (2024). Assessing educational progress: A comparative analysis of PISA results (2018 vs. 2022) and HDI correlation in the Philippines. *World Journal of Advanced Research and Reviews*, 21(1), 462-474.
2. Aflatoony, L., Wakkary, R. L., & Neustaedter, C. (2018). Becoming a design thinker: Assessing the learning process of students in a secondary level design thinking course. *The International Journal of Art & Design Education*, 37(3), 438-453. <https://doi.org/10.1111/jade.12139>

3. Ballen, C. J., Wieman, C., Salehi, S., Searle, J. B., & Zamudio, K. R. (2017). Enhancing diversity in undergraduate science: Self-efficacy drives performance gains with active learning. *CBE—Life Sciences Education*, 16(4), ar56.
4. Boller-Aying, S., & Villegas-Mendaño, R. (2024). Students' performance on the horizontal and vertical components of projectile motion using project-based learning. *Ignatian International Journal for Multidisciplinary Research*, 2(4), 1689–1704.
5. Braun, V., & Clarke, V. (2019). Reflecting on reflexive thematic analysis. *Qualitative Research in Sport, Exercise and Health*, 11(4), 589–597. <https://doi.org/10.1080/2159676X.2019.1628806>
6. Cooper, G., & Berry, A. (2020). Demographic predictors of senior secondary participation in biology, physics, chemistry and earth/space sciences: students' access to cultural, social and science capital. *International Journal of Science Education*, 42(1), 151-166.
7. Fitriyah, I. J., Saputro, S., & Sajidan. (2025, November). Effectiveness of the Problem-Based Learning Model with a Design Thinking Approach in Improving Students' Creative Thinking Skills; A Systematic Review. In *Journal of Physics: Conference Series* (Vol. 3148, No. 1, p. 012017). IOP Publishing.
8. Henriksen, D., Richardson, C., & Mehta, R. (2017). Design thinking: A creative approach to educational problems of practice. *Thinking skills and Creativity*, 26, 140-153.
9. Hilvano, C. A., PhD, R. V. M. (2026). Mobile-Assisted Experimentation Using the Phyphox Application: Effects on Grade 8 Students' Conceptual Understanding of Pendulum Motion. *International Journal of Research and Innovation in Social Science*, 10(26), <https://doi.org/10.47772/IJRISS.2026.1026EDU0410>.
10. Hoa, H. Q. (2025). Integrating design thinking into STEM education: Enhancing problem-solving skills of high school students. *Eurasia Journal of Mathematics, Science and Technology Education*, 21(4), em2611.
11. Interaction Design Foundation, Dam, R. F., & Siang, T. Y. (2021, December). What is design thinking and why is it so popular?.
12. Jaeger, A. J., Shipley, T. F., & Reynolds, S. J. (2017). The roles of working memory and cognitive load in geoscience learning. *Journal of Geoscience Education*, 65(4), 506-518.
13. Kolb, D. A. (1984). *Experiential learning: Experience as the source of learning and development* (Vol. 1, No. 1, pp. 270-289). Englewood Cliffs, NJ: Prentice-hall.
14. Ladachart, L., Radchanet, V., & Phothong, W. (2022). Design-thinking mindsets facilitating students' learning of scientific concepts in design-based activities. *Journal of Turkish Science Education*, 19(1), 1-16.
15. Landicho, C. J. (2021). Changes, challenges, and opportunities in teaching senior high school earth science amidst the COVID-19 pandemic. *Journal of Learning and Teaching in Digital Age*, 6(1), 55-57.
16. Moon, A. (2022). *Creating Prototypes: Products of the Design Thinking Process* (Master's thesis, SUNY Polytechnic Institute).
17. Mäkitalo, Å. (2016). On the notion of agency in studies of interaction and learning. *Learning, Culture and Social Interaction*, 10, 64-67.
18. Maneewan, C., Hemtasin, C., & Thongsuk, T. (2024). Design Thinking for Innovative Learning: Crafting a Collaborative Activity Package to Enhance Teamwork Skills in Science Education. *International Journal on Social and Education Sciences*, 6(4), 550-576.
19. Novawan, A., Ismailia, T., Zuhro, C., Utami, L. D., Pratama, M. R., Karimah, K., & Haq, R. N. (2024). Design thinking approach to powerful material development in educational contexts: From theory to practice. *International Journal of Studies in Social Sciences and Humanities*, 1(2), 125-145.
20. Pugh, K. J., Bergstrom, C. M., Heddy, B. C., & Krob, K. E. (2017). Supporting deep engagement: The teaching for transformative experiences in science (TTES) model. *The Journal of Experimental Education*, 85(4), 629-657.
21. Zhang, F., Markopoulos, P., & Bekker, T. (2020). Children's emotions in design-based learning: A systematic review. *Journal of Science Education and Technology*, 29(4), 459-481.