Science Education International
35(4),369-381
https://doi.org/10.33828/sei.v35.i4.8

ORIGINAL ARTICLE

Exploring Active Learning Strategies in Science among Senior High School STEM Learners and Teachers

Ananias N. Yunzal Jr.[1]*, Aubrey Ginelle Rallos[2], May Noren Nanud[3], Ma. Lina Ondoy[4], Jhun Matthew Ares[4], Marchee Picardal[6]

[1]Department of Teacher Education, Visayas State University, Baybay City, Leyte, Philippines, [2]Department of Teacher Education, Central Philippines State University, Kabankalan City, Philippines, [3]Department of Basic Education, Misamis University, Ozamiz City, Philippines, [4]Department of Education, DepEd, Ocana National High School, Carcar City, Philippines, [6]Department of Science Education, College of Teacher Education, Cebu Normal University, Cebu City, Philippines

***Corresponding Author:** ananias.yunzal@vsu.edu.ph

ABSTRACT

With the recent data revealing the performance status of Filipino learners in science aggravated by the negative effects of the pandemic, a concerted effort is directed toward exploring how learners learn science concepts in the current educational landscape to address issues of poor conceptual understanding and a learning gap. This qualitative study explored the perceptions of STEM learners on different ways of learning science concepts and how teachers developed the habits and attitudes of learning science among their students to develop conceptual understanding. Using a descriptive phenomenological approach, a semi-structured interview guide was conducted among 15 teachers with their corresponding students (n = 60) to explore their strategies and purposeful ways of learning and understanding concepts in science. Thematic analysis revealed five themes that describe STEM learners' science learning process: extended reading, recalling, and rewriting; seeking help from MKO (more knowledgeable others); self-directed learning; acquisition from learning resources; and experiential learning. Both learners' and teachers' narratives emphasized the need for diverse approaches catering to the needs, interests, and contexts of every individual to promote the science of learning among students. While learners are struggling to concretize abstract concepts in science, their varied intentional science of learning enables them to navigate in the learning process.

KEYWORDS: descriptive phenomenology, learning gap, science of learning, STEM learners, STEM teachers

INTRODUCTION

Science education is considered one of the gateway subjects to higher education and employment (Stott and Hobden, 2016). Departing from the traditional lecture type of instruction, student-centered teaching–learning processes are characterized by the use of active learning strategies (Lugosi and Uribe, 2020; Li et al., 2023). Active Learning Strategies (ALS, for brevity) are several competencies necessary for effective learning and retention of information that learners can later use (Weinstein and Underwood, 2014). Depending on the conditions under which information is needed, experts categorized learning strategies as either cognitive information processing or metacognitive strategies (Weinstein and Underwood, 2014) and were recently situated under the general framework of self-regulated learning or affective strategies (Stott and Hobden, 2016; Schellings, 2011). From the teacher's perspective, learning strategies are sequences of activities, largely under the deliberate, conscious control of the learner, that are selected from alternative activities to attain a learning goal (Garner, 1988), while from the student's perspective, these are observable patterns of behavior, controlled consciously or subconsciously by the student, that serve as tools for learning to occur (Chi and Wylie, 2014). As the educational landscape expands and systems and processes become more dynamic and technology-driven, the forms, styles, and strategies of active learning also diversify, prompting several educators and researchers to investigate the influence of ALS on learning outcomes across disciplines (Li et al., 2023).

Recently, with the emergence of blended learning and flipped classrooms, active learning has become so popular, as evidenced in the keyword analysis of 149 articles about flipped learning from 2000 to 2015 (Yang et al., 2019). In science, a lot has been examined in this research area. For instance, Best et al. (2012) looked into how explaining the text to oneself while reading a certain science text is influenced by several factors such as reading comprehension skill, prior science knowledge, and sentence difficulty. Lugosi and Uribe (2020) utilized combined active learning strategies such as interactive presentation style, group work with discussion and feedback, volunteer presentations of solutions by groups, raising students' learning interest towards specific topics, involving students in mathematical explorations, experiments, and projects, and last but not least, continuous motivation and engagement of students in improving the mathematical skills of undergraduate students. Kitchens et al. (2018) describe the CAPTIvatE scheme to highlight the interaction between fellow students and the instructor. Team-based learning, team discussions, immediate feedback, "doing real experiments, and real-world applications play important roles in increasing understanding of course content. Stott and Hobden (2016) did a case study of a gifted high achiever in learning science with the understanding that observing a gifted learner in action (in this case, learning physical science) might provide information that could be used to help underachievers. They identified the specific learning strategies that steer this gifted, high-achieving student's learning of physical science toward scientifically appropriate understanding, namely interrogating information, thinking it through, and organizing and linking. Recently, Theobald et al. (2020) further affirmed that active learning narrows achievement gaps for underrepresented students in undergraduate STEM education compared to those in traditional lecturing classrooms. Finally, Chi and Wylie (2014) emphasized that note-taking, concept mapping, and self-explaining are three specific engagement activities that facilitate students becoming more engaged with the learning materials in their laboratory classes, from passive to active to constructive to interactive, translating to increased learning, thus the ICAP hypothesis. It can be deduced that active learning engages students in the process of learning through activities and discussion in class, as opposed to passively listening to an expert. It emphasizes higher-order thinking and often involves group work. These classroom approaches that engage students in active learning improve retention of information and critical thinking skills and further increase the persistence of students in STEM majors (Theobald et al., 2020; Lugosi and Uribe, 2020; Nandigam, 2014). One of the identified challenges confronting active learning is how teachers incorporate these strategies into their courses without sacrificing coverage of content (Li et al., 2023). Moreover, attention should focus on how ALS facilitates learning and the considerations of how these strategies can be applied to maximize learning outcomes in the learning process (Leatherman and Cleveland, 2019).

The Philippine educational system is confronted with an alarming issue of a learning gap, if not a learning loss, due to the effect of the pandemic, resulting in the consistently low performance of students in standardized assessments. A call for students to have a deeper understanding so that they can make sense of and apply their learning to authentic situations has reverberated in science teaching in the Philippines (Picardal and Sanchez, 2022). Bernardo et al. (2023) classified the typical types of inquiries addressing science teaching and learning as (a) those that investigate the learning outcomes of particular instructional strategies and (b) those that look into student motivations and other non-cognitive student-level variables as predictors of learning and achievement. They further pointed out that metacognitive awareness of reading strategies is one of the many factors that explains why Filipino students are vulnerable to very low achievement in science, making this aspect one of the possible targets for reform in science education in the Philippines. Moreover, the rapid change brought by Industry 4.0 also brings challenges to science education implementers, for the country needs to ensure that it can adapt to emerging technologies like AI and robotics (De La Cruz, 2022). While there are few studies investigating the effectiveness of active learning strategies in teaching science (Moya, 2014; Malanog and Aliazas, 2021; Pacala, 2021), most of these studies are quasi-experimental in nature, and there is a dearth of investigation exploring the experiences of STEM teachers and students vis-à-vis active learning strategies.

METHODOLOGY

Research Design

Descriptive phenomenology was used in this study to explore the STEM learners' perceptions of various science learning methods and teachers' strategies for cultivating positive learning habits and attitudes toward conceptual understanding. Phenomenological research, according to Moser and Korstjens (2018), is iteratively focused on capturing the essence of the participants' meaning. Descriptive phenomenology was selected as the research methodology because it was thought to be a suitable approach for understanding the ways that teachers and students learn and comprehend scientific concepts. This is due to Husserl's belief that reality cannot be examined separately from the consciousness of individuals who experience it (Morrow et al., 2015).

Research Environment

The location of the research study plays considerable significance in shaping the outcome of the research. In this instance, the research was carried out within the Visayas and Mindanao Region, in particular areas of Negros Occidental, Leyte, Cebu, and Misamis Occidental, which characterized a diverse population with a significant number of students and teachers who learned and taught science. The Visayas and Mindanao regions offer a unique setting that enriches various fields of study and is home to a number of senior high school schools offering STEM (science, technology, engineering, and mathematics) strands. Exploring active learning strategies in this context was crucial for understanding how to improve science education and effectively engaging students in the different learning areas of STEM. In this study, STEM refers to learners who are bona fide students in Grades 11 and 12 and are enrolled in the academic track in which STEM strand is included as per K-12 curriculum of the Department of Education of the Philippines. On the other hand, STEM teachers are those who are teaching different science subjects (e.g. Biology, Chemistry, Physics, and Pre-calculus) in Science, Technology, Engineering, and Mathematics strands in academic track. Exploring active learning strategies in science among senior high school STEM learners and teachers in the Visayas and Mindanao regions paves the way to valuable insights for improving science education, learning science, enhancing student lesson engagements, and learning outcomes, and promoting innovation in teaching delivery and practices.

Research Participants and Sampling Procedures

This study is qualitative in nature, so non-probability sampling was used, specifically purposive sampling. In this study, 15 full-time senior high school science teachers (coded as TP, Teacher Participant) and 60 students (coded as SP, Student Participant) enrolled during the 2023–2024 academic year were selected. They were chosen for their experience and the subject of the research.

The teacher participants in this study were selected based on the following selection criteria: (a) having been a public school senior high school science teacher; (b) having worked as a teacher for at least 3 years during the school year 2023–2024; (c) having taught either of the subjects, Earth Science, Biology, Physics, or Chemistry to grade 11 or grade 12 students; (d) being able to discuss different teaching strategies for science education; and (e) being willing to be part of the study.

On the other hand, the student participants were selected using the following selection criteria: (a) having been officially enrolled in senior high school for the school year 2023–204; (b) currently taking either of the subjects, Earth Science, Biology, Physics, or Chemistry in Grade 11 or 12, employing maximum variation sampling; and (c) willing to be part of the study.

Research Instrument

This study utilized in-depth interview guide questions thoroughly examined by an expert in the field to determine the strategies that the students are using in learning science and the strategies used by teachers for learners to learn science. There was only one major question for both students and teachers. The question for the students was, "What are your strategies to learn science?", while the teacher's question was, "What are your strategies for learners to learn science?". It was then the skills of the researchers to have the follow-up questions to enrich and get the amount of substance that they wanted to get from their respective participants.

Data Gathering Procedure

The researchers planned a systematic process and sought authorization from the principals of the respective schools. This research study has gone through thorough revisions.

To collect the data, the researchers prepared interview guides, which eventually served as the researchers' guide in organizing the data. Before proceeding with the collection of data, the researchers handed out an informed consent form for them to be aware of and educated about the goals and scopes of this research study.

Data collection was conducted through a combination of face-to-face and various online platforms like Zoom and Google Meet, utilizing semi-structured interview guides. Informants were encouraged to express their answers to the questions given and to share their experiences from their perspectives. Each interview lasted for about 15–20 min per session (3 sessions), and all of them were conducted by the main researchers. At the end of each interview, the researcher reminded the informants about follow-up interviews to discuss the study findings and ensure that the study findings reflect their personal experiences.

From the start, descriptive phenomenology is employed. To be able to transcribe and properly collect the data, the researchers will use a voice recorder to record the participants' responses.

Data Analysis

Making sense of data is one of the most important parts of doing research, as it will provide insight related to the phenomenon of interest, leading to an understanding of the emerging patterns (Simplilearn.com, 2023). In the context of qualitative data analysis, textual data, as manifested in the interview transcripts, plays an important role in providing emerging themes and patterns (Miles et. al., 2014). As mentioned, emerging themes provide the condensed form of the data as a result of thematic analysis; thus, this study utilized the Braun and Clarke (2006) thematic analysis method. In this study, the six phases of thematic analysis were followed: familiarization of the transcript, generating initial codes and themes, review of themes, defining and redefining themes, and eventually the write-up (Braun and Clarke, 2006).

In data analysis, interview transcripts derived from the interviews of the participants were utilized. Aside from the familiarization (Braun and Clarke, 2006) of the interview transcriptions, researchers also employed a constant comparison technique (Corbin and Strauss, 2015) to ensure the credibility (Miles et. al., 2014) of the emerging themes. Although the systematic study of Hennink and Kaiser (2022) mentioned at least nine participants to generate enough data to attain saturation, this study, however, utilized transcription more than what is suggested. Overall, this study analyzed over 200 significant statements from the participants, which was the basis for the generation of themes.

Ethical Consideration

The researchers considered the ethical considerations required for this undertaking. The data gathering was done after seeking approval from the respective DepEd Schools Division Offices and Principals, as well as after the key informants had been informed of the objective of the study and had been provided informed consent. The researchers also informed the key informants that their participation is voluntary and that they are free to withdraw their participation at any time. This study also ensures that confidentiality, anonymity, and privacy are maintained in data gathering and analysis.

RESULTS AND DISCUSSION

Results

After the rigorous thematic analysis of the interview transcripts provided by the participants on the strategies that students employed in learning science and the strategies used by teachers for learners to learn science, five themes emerged as shown in Table 1.

Table 1: List of Themes, and Strategies of Students and Teachers in Learning and Teaching Science

Theme	Learning Science Strategies (Students)	Learning Science Strategies (Teachers)
1. Extended Reading, Recalling, Rewriting and Review	• Note-taking • Rewriting while studying • Comprehensively reading of notes • Scanning of notes regularly	• Journal article analysis • Simplification • Use of analogy • Mnemonics • Memory-aid • Hand gestures
2. Help from MKO (More Knowledgeable Others	• Peer tutoring • Listening vividly to the teacher • Group study • Asking ideas from the seniors and from former teachers	• Entertaining questions • Explicit instruction • Study buddy grouping • Integrative interdisciplinary approach
3. Self-directed Learning	• Voice recording while reading notes • Writing formulas and word definitions in sticky notes and pasting it around the room • Recording the lessons on the phone and listening to it repeatedly • Studying regularly as early as 3 AM • Listening to music while studying	• Game-based activities • Realias • Differentiated instructions
4. Acquisition from Learning Resources	• Watching online videos of the lessons • Researching online reading materials • Searching tutorial videos on YouTube • Searching sample problems from online sources • Searching online or reading for advanced study of a certain topic	• Use of infographics • STEMTOK (TikTok) activity • Virtual and interactive simulation
5. Experiential Learning	• Putting the lesson in a real life situation • Conducting simple experimentation	Project-based learning Laboratory experiment Field work

Theme 1: Extended Reading, Recalling, Rewriting, and Review

In exploring how STEM students approach learning science, a diverse array of strategies emerged, showcasing the adaptive nature of their learning process. One prevalent strategy observed among students is their approach to extended reading and engaging with educational materials. Three student participants emphasized the value of using the internet after class, whether through Google searches or YouTube videos, to enhance their learning. The student participants said:

> *"If there are topics that the teacher has not elaborated on further, I research related articles on Google."* Student participant 2
> *"If I find it difficult to understand assignments, schoolwork, or upcoming quizzes at home, I always browse the internet and look for tutorials related to our lectures."* Student participant 3
> *"When I study science, which is one of my favorite subjects but not my strongest, I conduct research and watch video lessons on YouTube."* Student participant 4

The students' utilization of the internet as a versatile avenue for exploring topics aligned with the cognitive theory of multimedia learning (Rudolph, 2017), which emphasizes learning from words and pictures. Remarkably, research by Herrlinger et al. (2017) demonstrated that students comprehend science text more effectively when accompanied by diagrams and steps, indicating that these students, who are also visual learners, strategically employ online resources to enhance their understanding of scientific concepts. One teacher participant also aligned its teaching strategies to this method employed by students in learning science. As the teacher participant shared,

> *"In subjects like science, not everything can be realized through direct teaching, such as teaching about the solar system and then experiencing it first-hand. That's why videos, pictures, and PowerPoint presentations are utilized."* Teacher participant 2

This implies that teachers are also adapting to students' learning preferences by incorporating multimedia elements such as videos and presentations into their lessons, which aligns with Rudolph's (2017) cognitive theory of multimedia learning.

Another learning approach in science employed by students is their unique strategies for recalling information. One student participant utilizes mnemonics as a memory aid to better retain information or Mayer and Moreno (2003), showcasing a proactive approach to memory retention:

> *"...sometimes I use mnemonics to better retain information or terms."* Student participant 2

A teacher participant utilized a similar teaching approach to instruct lessons necessitating memorization.

> *"…for topics that need memorization, I teach the class how to do mnemonics so that they can recall lessons easily."* Teacher participant 3

This mnemonic technique makes learning more engaging and enhances recall by presenting information in personal, surprising, or humorous ways (Adepoju, 2014). Whitescarver (2018) effectively utilized mnemonic devices to enhance the acquisition and retention of vocabulary among high school students with learning disabilities. This merely implies that using mnemonic devices in conjunction with instructional techniques might improve students' comprehension and retention of material, especially for those who struggle with learning.

One student participant appears to be taking a methodical approach to exam preparation as they concentrate on becoming familiar with terms to make recall easier:

> *"My strategy is always to familiarize myself with the keywords so that terminologies can be easily remembered, especially if there are upcoming exams or quizzes involving Earth Science and Biology."* Student participant 3

Analogous to mnemonic techniques, these keyword techniques aid in learning by giving abstract notions greater substance (Lubin and Polloway, 2016). According to Cioca and Nerisanu (2020), this approach fosters students' creativity while also improving learning performance. This demonstrates how employing these strategies fosters both academic success and creativity in students. It also demonstrates how critical thinking abilities and cognitive development are fostered by these strategies.

Another participant employed a different recall technique. A student participant adopted a conversational learning method, engaging in a dialogue with themselves while studying and reinforcing their understanding through repetition, highlighting an interactive and repetitive approach to memory consolidation.

> *"When I study to understand the lesson, I read through each meaning or lesson as if I'm having a conversation with myself while studying. Then, I repeat it to ensure that I truly remember it."* Student participant 7

The usefulness of this method is validated by MacLeod and Bodner (2017), who demonstrated that students' memory of textual content is superior when they mutter while studying words, sentences, and passages compared to when they read silently. This approach, termed the "production effect" by MacLeod and Broadner (2017), aligns with the "generation effect" in memory retention (McCurdy et al., 2020) by promoting discussion and repetition as means of active involvement with the content.

Rewriting and summarizing lecture material is another productive study strategy that students have adopted and that has grown to be an essential part of many study regimens. For example, a student participant actively participates in class discussions by taking notes. After that, at home, the participant carefully paraphrases and summarizes the lecture content, comparing it to their notes from class to make sure they fully grasp it.

> *"I take notes when the teacher is having his or her discussion in front. When I got home, I wrote the presentation for lecture that was recently discussed and then compared it with my notes taken during the discussion to see if there was missing information."* Student participant 1

Similarly, another student participant adopted a proactive learning strategy by previewing the material before studying. The participant then dedicated about 30 min to memorizing key concepts before writing down their understanding on paper.

> *"When studying, ma'am, I preview the material beforehand. I try to remember for about 30 minutes, then I write down on paper what I've learned. That's how I study science."* Student participant 12

Boyle et al. (2015) emphasized how students frequently take notes that are insufficient and sparse, missing crucial lecture elements. According to Shi et al. (2020), this difficulty is worsened by the fact that students are usually dual-tasking, trying to comprehend the content of the lecture while simultaneously transcribing it. However, as noted by Kane et al. (2017), taking notes still helped students retain information and focus their attention on the topics covered in class. Fanguy et al. (2017) conducted Salame and Thompson (2020) a study that extended the significance of note-taking techniques by demonstrating that group note-taking improved student retention while individual note-taking led to better academic writing outcomes. Their results demonstrate the diverse impact of distinct note-taking strategies on various aspects of education. Courtney et al. (2022) agreed with this result, arguing that collaborative notetaking can successfully solve the problem of insufficient note-taking and enhance recall ability by allowing students to work together to make more comprehensive notes.

These results demonstrated STEM students' reviewing techniques as complex, comprising both active participation and contextualization of the material they have acquired. In essence, they highlight the interplay between students' methods of learning and their quest for scientific understanding. The abovementioned active learning strategies are proactive and flexible approaches to understanding scientific concepts. This emphasizes the intricacy and diversity of the learning process in science education.

Theme 2: Help from MKO (More Knowledgeable Others)

Learning science is one of the most interesting and challenging areas of discipline among STEM students. It gives them the opportunity to gain a better knowledge of how and why things work. Most of the participants say that help-seeking is an essential tool for students' success in learning science by employing a group study. By doing so, they can share their thoughts and insights on a particular topic or lesson.

> *"There are times that I join group study among my classmates if there are topics or lessons that are not so clear to me and give me confusion. There are even times that I am the one that initiates the group study among my classmates"*. Student participant 4

"If there are parts of the topic that I cannot understand well, I ask for assistance from my classmates. I seek help from them so that I can understand the lessons well". Student participant 7

"I seek assistance for tutoring from my classmates who are much more knowledgeable than me for a clearer understanding". Student participant 9

Flores et al. (2018) stated that the importance of the peer tutoring instructional strategy includes improving students' academic performance, communication skills, and enthusiasm to learn. It also instills a sense of responsibility and builds self-confidence. Students are more involved in learning when they work with other peers (Hwang et al., 2019) because they feel more connected with their peers when learning (Hanson et al., 2016). In addition, it enables them to work as a team, provide and accept responses, and appraise their learning activities (Hanson et al., 2016).

Fundamentally, peer tutoring refers to a learning environment where students learn together and from each other as equal learners without exerting authority over any learner, based on the ideology that "students learn a great deal by explaining their ideas to others and by participating in activities in which they can learn from their peers" (Boud et al., 2014). Consequently, peer tutoring upholds intellectual development and improves academic and social skills for both tutor and tutee (De Backer et al., 2015; Eslami et al., 2015). Inuwa et al. (2017) asserted that peer tutoring is one of the most effective learner-centered strategies to improve students' academic achievement and other related learning outcomes. This theme is further supported by the recent studies investigating other learning areas teaching biology concepts (Azubuike, 2012), secondary school economics (AbdulRaheem et al., 2017), technical drawing (Ogundola, 2017), and mathematics (Moliner and Alegre, 2020). To elaborate, some learners nuanced:

"*Through peer tutoring, I was able to grasp the lessons most especially when it comes to calculation. Me and my classmates share ideas and insights and eventually come up with a simple summary to understand and articulate the science concepts."* Student participant 9

Peer-tutoring is one of the more extended forms to support new student adjustment (Ruffalo Noel-Levitz 2015), and it can be defined as the acquisition of knowledge and skill through active helping and supporting among status equals or matched companions, where both tutees and tutors benefit from the transaction (Topping, 2015).

A teacher key informant mentioned that he used to have a grouping or pair buddy when giving activities to his students, especially on calculations.

"I usually grouped my students when giving activities, most especially on the topics that require calculations. I've noticed that they are more engaged and interested when they have someone to talk to and ask to. They got passing scores and some of them got higher and perfect scores". Teacher participant 1

Peer learning or cooperative learning are umbrella terms (Van Ryzin and Roseth, 2018) that include reciprocal teaching, peer tutoring, peer coaching, jigsaw, and other group-based activities. The advantage of cooperative learning is that it can improve students' self-confidence and motivation, as well as their sense of responsibility in learning. While this makes it easier for students to learn, the disadvantage is that it requires more time to prepare, implement, and manage (Ghufron and Ermawati, 2018).

Many courses in different majors at universities around the world have adopted peer learning or cooperative learning methods, achieving good results. Science, Technology, Engineering, and Mathematics (STEM) courses adopt the "peer-learning assistant" model, thus enabling students to achieve learning improvement (Gong et al., 2020).

Additionally, cooperative learning has improved the critical thinking of engineering ethics courses (Hsu, 2021) and the positive academic classroom community of natural sciences and other courses. Furthermore, cooperative learning has been shown to improve students' critical analysis, communication, teamwork, and problem-solving skills in food process systems engineering courses (Munir et al., 2018). Furthermore, creativity, deep learning, and teamwork skills were also found to improve in chemical engineering students in three courses (Azizan et al., 2018). Higher learning benefits and transferable skills were obtained in an introductory organic chemistry course (Canelas et al., 2017).

Theme 3: Self-directed Learning

Self-directed learning is a multi-dimensional construct that is considered from varying perspectives across many disciplines, particularly in STEM education because it incorporates the critical role of mindset and motivation (Brandt, 2020; Panadero and Alonso-Tapia, 2013). In this theme, this aspect is one of the active learning strategies employed by learners in learning abstract concepts in science. As evidenced by their experiences:

"My different strategies Sir, I will try to really listen to the discussion, try to understand the concept, if I don't really understand, I will take down notes with the important keywords. Then, when it was late at night, I immediately did google searches, answer modules, watched YouTube videos, to further understand the concepts that were discussed." Student participant 1

"I also self-study sir like looking for websites full of science concepts, downloading, reading, and answering modules. These provided me with lots of information that I am satisfied with, sir, and I will be able to say that I am ready for quizzes and exams". Student participant 3

The students have manifested control of their learning process by adapting active learning strategies that will supplement their understanding of concepts in science Urdanivia et al., 2023. This observation is supported by Dacumos (2023), who asserts the importance of self-directed learning, teamwork, and peer-review assessment features in STEM education. Students who are internally driven to learn and who have a strong belief in their capabilities will find all means to master competence in academics (Knowles, 1975), even without the help of other people (Coros and Madrigal, 2021).

The participants of this study are students who utilized flexible learning modalities (e.g., online classes, modular approaches, and blended learning approaches) during the COVID-19 pandemic. At that time, teachers had to create active learning strategies to facilitate students' self-directed learning, considering the absence of teachers' physical monitoring and onsite consultation.

> *"With my experience during the COVID-19 pandemic, I faced the challenge of adapting to remote learning and creating active learning strategies to support students' self-directed learning in the absence of face to face interactions. I used problem-based inquiry and research projects, were validated and applied in online assignments, outputs and performance tasks to enhance students' science learning experiences and critical thinking skills."* Teacher Participant 3

This finding supports the claim of Pepito and Aclidan (2022) that there is a significant relationship between digital literacy, self-directed learning, and online learning success. Students with high digital literacy and self-directed learning skills are more likely to succeed in online education Gerard et al. (2022). Consequently, teachers have employed active learning strategies to facilitate the self-directed learning of learners.

> *"So, as a Science teacher, I used student-centered strategies to ensure that the competencies are fulfilled while enhancing students' critical thinking and curiosity. I mostly employed inquiry-based learning or IBL to encourage students to actively express scientific concepts through inquiry research and also discovery, and in this way, it also improves their critical thinking and comprehension*." Teacher participant 1
> "*I must consider first the type of learners and their learning styles as well as the topic. Science strategies like hands-on experiments, inquiry-based learning, and project-based learning are best active learning strategies where critical thinking and problem-solving and deeper understanding of science concepts are developed."* Teacher participant 2

The shared experiences of STEM teachers capture the essence of promoting self-directed learning, metacognitive awareness, and 21st-century skills and competencies of learners to promote their readiness for online learning and other learning modalities (Karatas and Arpasi, 2021). Self-directed learning is nurtured through group problem-solving, teamwork, and community involvement, along with chances to exercise autonomy, initiative, and accountability.

Theme 4: Acquiring Information from Learning Resources

In the context of facilitating STEM learning, the use of varied educational resources plays an important role in developing conceptual understanding. This theme describes how learners utilize both online and digital as well as print-based and traditional learning materials. It is a fact that the synergistic use of learning resources gears toward success in the learning of concepts of science (Mayer, 2008; Jaeger and Fiorella, 2023). Unlike before, students can have different options on which form and sources of information they have to use. Some of the learning resources include textbooks, multimedia resources (Aydin and Cagiltay, 2022; Ida et al., 2021), and activity-based materials, as well as technology-aided resources such as websites and simulations (Bybee and McCracken, 2011).

> *"...if I am confused with the lessons, I will look for the topic in the module I downloaded from the LMS and read if I am not satisfied then I will search in the internet, research gate or watch educational videos"* Student Participant 14
> *"…there are already prepare modules which are found in the DepEd-BLR, what I do is to download those relevant materials and give to students. I have to print it first before I gave the material to my students. I also provide video links from YouTube as supplementary to the distributed printed modules…"* Teacher participant 16

To note, this theme is divided into sub-themes according to typologies of learning resources: (1) print-based and traditional resources and (2) digital and online resources.

Print-based and traditional resources

Despite the availability of varied learning resources, the most commonly used by students are print-based and traditional learning resources such as textbooks, worksheets, and lab manuals. This is due to the dependence on the immediate availability of the said resources, which provide equitable access to learners regardless of socioeconomic status and location. The relevance of print-based and traditional learning resources amidst the emergence of digital-based materials supports the claim of Akyol (2015).

> *"...If I have free time, especially since we only have a few subjects, I will stay in the library to read books about physics. The subject is difficult and requires time to study. I would prefer books because I can focus..."* Student participant 16
> *"…we have very limited number of books issued from the central office, so what I did was to print the softcopies of modules available and provided it to my students. I am doing this because I that there are students who do not have access to internet so their learning won't be compromised…"* Teacher Participant 3

Moreover, some of the participants emphasized their preference on the use of books for them to stay focused on reading thus avoiding unnecessary use of phone scrolls. This experience of some participants is aligned to the study of Sana et al. (2013). In addition, the use of printed learning materials not only allows students to focus but also provides an avenue in developing core skills (Willingham, 2009), on top of that is the portability and flexibility of the materials (Roffi et. al., 2023).

Digital and online learning resources

Another typology of learning resources is those that can be accessed anytime and anywhere. The emergence of internet connections revolutionized the landscape of education (Derksen et al., 2022), especially during pandemics where face-to-face classes were disrupted and continuity of learning was of prime importance (Voogt et al., 2021). Online learning resources include but are not limited to, video lectures, simulations, and other downloadable resources whose primary function is to facilitate learning among students independently (Vijayan, 2021).

> "*...when I find the topics interesting what I am going to do is I will use the Internet and go to the youtube website and watch videos that are related to the topic I am interested with. But of course, you have to be interested first… I love math-related subjects including physics it really tickles my interest, aside from videos I also read research articles in journals…*) Student participant 15
> *"…during pandemic, all the teacher in our school were encouraged to make recorded video. Those videos that we recorded usually we save it in our flash drive or sometimes we posted it in our YouTube channel for our student could watch it anytime they want…"* Teacher participant 10

This shared experience of the participants in learning science through the use of online learning resources is highly associated with the desire to learn, also known as self-regulated learning (Hadwin et al., 2016). Furthermore, Tanti et al. (2020) supported this notion by emphasizing that self-regulated learning plays a crucial role in the learning process among students in science, especially in times of crisis.

Theme 5: Experiential Learning

Experiential learning significantly had an impact on students' and teachers' understanding and engagement with science education, specifically in the areas of science, technology, engineering, and mathematics (STEM). Duff (2004) and Alkan (2016) emphasized that Kolb's experiential learning has a reputation as one of the most successful learning models. It was expounded as an active learning process in which students "learn by doing" and by reflecting on their experiences through project-based learning activities, laboratory work, and fieldwork (Coker and Porter, 2015). Research studies highlighted the advantages of experiential learning in science education. For instance, Bybee (2015) urged students to actively create their knowledge, hone their problem-solving skills, and participate in scientific inquiry through experiential learning. A teaching approach that uplifts hands-on and minds-on learning through actively involving students in the teaching and learning process.

> *"For my almost six (6) years in teaching science, I have provided experiential learning activities towards my students like conducting laboratory experiments, build models, realia, manipulate materials to explore the application of different concepts in science. I let my students do these stuffs in groups or individuals in the laboratory with practical applications and the theories they have learn from the lessons especially in my STEM class in my Biology subject."* Teacher participant 63

Learners create a new body of knowledge through a transformational learning experience that is based on the perspective that, when they learn, holistically incorporates one's experiences into learning (Jennings and Wargnier, 2010; Nwuba and Osuafor, 2021). And, when learners develop, progress, and use her or his learning strategies, it will boost teachers teaching strategies as well, especially in teaching science, leading to this sub-theme.

Project-based learning

In K–12 classrooms, STEM increases enthusiasm to learn and raises student interest through success in these interdisciplinary subjects (STEM Integration in K-12 Education: Status, Prospects, and an Agenda for Research, 2014). The clear links between STEM and PBL are focused on using interdisciplinary studies to improve student comprehension and self-efficacy. Thomas (2000); Hugerat (2016) briefly define project-based learning as ''a model that organizes learning around projects.'' Students enhanced their learning process by actively participating in project-based activities (e.g., developing a geologic time scale using tissue paper, creating DNA models, and making a presentation based on research findings about environmental solutions). Students' accomplishments increased not just in the scope of a project but also in other fields of expertise (Almulla, 2020), for they believe that the skills they have acquired through project-based activities will benefit their future career.

> *"In science, especially subjects like General Biology, General Chemistry, and General Physics have lots of projects. These three, Ahmmm.So far, I have participated in activities that were given by my teachers. Like, making video presentations or PowerPoint from science research, not to mention during pandemic times, lots of project-based, in a way that I learn more in doing projects while also knowing the concept, it's my way of learning too".* Student participant65

On the other hand, teachers incorporated PBL in teaching science to develop the critical thinking skills and innovativeness of students using science concepts, address real-world problems, and foster a deeper appreciation for science in the classroom Yew and Goh (2016). They collaborated with other educators to design and implement PBL units that align with science curriculum standards, like conducting training and seminars for project-based learning.

> *"As a teacher, I employ my students on projects with the subject concept, for example in my Earth Science in STEM, the ones I let my class devise a mini-ecosystem on a basin and do collaborate for another subject. With this, I can reflect on my experiences like the things I have learned from my previous school of employment and incorporate them in my class, such as refining projects for future classes."* Teacher participant 62

Laboratory experiments

Experimentation specifically includes a large percentage of scientific process skills and should be prioritized for in-depth investigation when carrying out multiple tests (Martin, 2012; Conchas et al., 2023). Research findings indicate that the best lasting and efficient way to obtain knowledge in learning science would be through a laboratory method (Bağcı and Şimşek, 1999; Güven and Gürdal, 2002; Alkan, 2016). Laboratory practices fill in the gaps between science theories and practices and help students define concepts in science comprehensively.

Engaging in this process of conducting simple experiments such as frog dissection in biology and extracting phytochemicals from plants in chemistry, students not only learn about specific scientific concepts but also develop important skills such as critical thinking, problem-solving, and data analysis. In addition, they gain a deeper understanding of the scientific method and how it is applied in real-world situations when developing STEM capstone projects to solve environmental problems in the community.

> *"As a student, I have learnt to strategize my science learning through doing laboratory experiments religiously. I am always looking forward to the outcome of every experiment and do my utmost observation, especially during our capstone research project on making a prototype on flood detection using Arduino sensors."* Student participant 67

The function of the teacher should be that of a guide who shares the significance of educating science as well as the obligation and excitement for gaining scientific understanding and simultaneously directs the classes, especially in laboratory practice (Ministry of National Education, 2017). Moreover, Hofstein and Lunetta (1982) Teachers in science have frequently emphasized that learning is enhanced by laboratory actions. Furthermore, science educators attended workshops or seminars on effective laboratory practices in science education. They can collaborate with science educators and laboratory technicians to develop and implement engaging experiments that align with curriculum objectives.

> *"My class is in lecture and laboratory. Most often is in the laboratory because mostly students' students' learn more and understand the concept if they can see them visually or do it. But I encounter more concerns since our laboratory doesn't have much materials, so I watch and search on workshops on youtube or online for contextualization style. And sometimes, I provide them with a simulation (in Phet) if time doesn't permit for a laboratory or any virtual laboratory site."* Teacher participant 61

Fieldwork

Science educators have advocated for the use of outdoor areas as a practical teaching strategy for over 40 years (Brennan, 1967; Disinger, 1984; Leftridge and James, 1980; Prather, 1989; Stapp, 1970; Jose et al., 2017). Field trips in the great outdoors where students engage in hands-on activities indicate that engaging in local environment-related activities enhances students' learning in many areas, such as seeing organisms in reality and gaining a better understanding of the actual landscape of plants and animals that live within. Even brief, one-day fieldwork in the outdoors can improve knowledge, attitude, and feeling of interconnectedness with the natural world (Kossack and Bogner, 2012).

> *"In my STEM class in their capstone project, we have visited different industries based on their specialization like engineering, life sciences, and data science for their capstone project with the application on the concepts of their learnings in science."* Teacher participant 62

These findings are supported by each sub-theme of project-based learning, laboratory experimentation, and fieldwork. Engaging in experiential learning activities that explored active learning strategies in science, both STEM students and teachers developed a deeper understanding of scientific concepts, improved their problem-solving skills, and enhanced their overall learning experiences. Both students and teachers should be encouraged to reflect on their experiences with active learning strategies in science, so it could provide opportunities for them to give and receive feedback on their learning processes and outcomes.

DISCUSSION

The results of this study highlight the multifaceted approaches students and teachers use in the STEM classroom all geared towards positive learning outcomes. The interplay between traditional, collaborative, technological, and experiential strategies underscores the need for a holistic framework in STEM education through the lens of ALS. Teachers should continue integrating innovative and student-centered practices to foster active learning, critical thinking, and real-world problem-solving skills among learners using varied strategies designed to promote peer interaction and social interdependence (Arthurs and Kreager, 2017; Mallillin et al., 2021). With the independence of learners on technological tools such as laptops, incorporating traditional methods (i.e., rewriting notes, scanning materials, and recalling information) is still relevant to learners based on the principles of cognitive load theory, which emphasizes the organization of information to reduce mental effort and facilitate retention (Sweller, 2011). Authors in this research area have unanimously advocated (Chi and Wylie, 2014; Theobald et al., 2020; Lugosi and Uribe, 2020) on the critical role of ALS. Consequently, as facilitators of learning in the 21st-century classroom, teachers complement these strategies through techniques like mnemonics, analogies, and simplifications to bridge the gap between complex scientific concepts and students' understanding (Picardal, 2019). Several abstract concepts in science can be delivered through collaborative learning opportunities, such as peer tutoring programs, study groups, and interdisciplinary projects, to capitalize on the benefits of collective knowledge-building.

With several potential sources of distractions among learners, promoting self-regulation through these ALS can help learners take ownership in the learning process as they interact with their peers, with the content, with the teachers and community. Zimmerman (1995) clearly describes that self-regulation involves more than metacognitive knowledge and skill, it involves an underlying sense of self-efficacy and personal agency and the motivational and behavioral processes to put these self-beliefs into effect. The generation of learners in the 21st-century classroom has a higher sense of autonomy and self-regulation in their learning process, and they have employed innovative self-directed strategies, such as voice recording notes, writing on sticky notes, and scheduling early study sessions, that allow them full control of how and what they learn. Teachers' use of differentiated instruction and game-based activities supports these efforts, allowing students to explore content in ways that resonate with their unique learning styles. Such pattern in the learning dynamics is due to the increasing reliance on digital resources, such as YouTube tutorials, online readings, and interactive simulations, signals the growing role of technology in science education. Meanwhile, teachers' use of STEMTOK, infographics, and virtual tools to enhance content delivery and classroom engagement. Students' and teachers' emphasis on hands-on learning, such as experimentation and real-life applications, underscores the value of experiential learning in making science relevant and engaging (Kuh, et al., 2006). This aligns with Kolb's Experiential Learning Theory, emphasizing the importance of active participation and reflection in constructing knowledge. The different strategies reported by both teachers and learners on how to engage themselves in the science learning process can shed light not only on the cognitive and affective domain but also on the psychomotor aspect that is involved in an effort of doing meaningful learning activities and to make them conscious of why and how they are doing it.

CONCLUSION

The research findings reveal that STEM students employ a wide range of learning techniques to improve their understanding of scientific ideas, such as conversational learning, mnemonic devices, extended reading, and keyword mastery. These varied approaches highlight the flexible nature of students' learning strategies, highlighting the dynamic element of the learning process in science education. Understanding and embracing the diversity of students' learning styles can enable teachers to modify their methods and create a more engaging and effective science learning environment. STEM students usually do group study and peer tutoring to improve their learning comprehension and retention of the lessons. The application of peer learning can significantly improve examination results, problem-solving skills, communication skills, teamwork, and time management. This strategy in learning science is widely used by students, which promotes meaningful learning, strong collaboration, and potential partnerships within and across learning communities. It is also revealed that students' intrinsic mechanisms of learning science play an important role. This mechanism is manifested through self-directed learning among students. In line with this, students were able to gain knowledge by accessing information from print-based and traditional as well as digital and online learning resources. Moreover, results further suggest that students learn more meaningfully when there is engagement with experiential learning methodologies employed both inside and outside of the classroom.

RECOMMENDATION

The processing of information and learning is varied among learners. There are different means by which STEM students learn the concepts and competencies in science as evidence in the different active learning strategies/techniques they employ to keep themselves engaged in the science learning process. Considering the findings in this study, it is recommended to explore varied ALS that are fit not only for face-to-face classroom set-up but also for blended learning, asynchronous, and all other modalities to ensure an enhance learning experience regardless of the absence of teachers. Training programs for science educators should emphasize the use of multimodal teaching tools (e.g., visuals, gestures) to address the varying cognitive, affective, and psychomotor needs of learners long with their technological skills and interests.

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