



Positive impact of formative assessment on science subject learning: A case study of an international private school

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ABSTRACT

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Addressing challenges in science education and enhancing students' learning experiences requires a comprehensive understanding of effective formative assessment practices. This study aims to investigate students' perspectives on formative assessment, particularly Classroom Assessment Techniques (CATs), in science education and explore their positive impact. Two research objectives were established: (1) to explore students' perspectives on CATs and (2) to identify students' reasoning on CATs. Students at an international private school who had been introduced to CATs and had used these techniques throughout their learning sessions were the focus of this qualitative research. In this study, 15 students participated in an online survey, out of whom three participants were randomly selected to participate in individual, in-depth, semi-structured interviews conducted. The students also signed informed consent forms, indicating their agreement to participate in the study. A series of interview protocols were designed. Regarding the perspectives on CATs, participants' responses were categorized into two common themes: (i) the ability to relate science to daily life and (ii) enhancement of understanding of science subject. Meanwhile, students' reasoning behind CATs was categorized into three common themes: (i) self-directed learning, (ii) aid in memorization, and (iii) reduction of feelings of isolation. The findings can provide both educators and students with a deeper understanding of the benefits derived from implementing CATs and how these techniques contribute significantly to the progress of teaching and learning processes.

Contribution/Originality: This study provides novel insights into student perspectives on Classroom Assessment Techniques (CATs), focusing on the progress of teaching and learning processes, in general, and their impact on critical thinking, practical application, and formative feedback, in particular. It also makes a unique contribution to the field of pedagogical research by highlighting the dynamic role of educators.

1. INTRODUCTION

Formative assessment is the process of gathering evidence from classroom activities to adapt the teaching and learning experience to better meet the students' needs. This process involves self-assessment by both teachers and students and includes classroom evaluations that provide data for feedback to shape the teaching and learning environment. Effective classroom assessment techniques should answer the questions "What are the students learning?" and "How effectively is the teacher teaching?" (Enerson, Plank, & Johnson, 2007).

The introduction of easy, non-threatening, and non-graded classroom assessment techniques aims to make the teaching and learning process engaging and entertaining while providing ongoing feedback to both teachers and students (Lakshmi & Majid, 2019). Informal evaluations can be carried out spontaneously and without prior planning, allowing students to complete them unnoticed (Mertler, 2017). Examining the challenges in learning that result from the pedagogical instruction delivered in the classroom can be an effective way to approach the problem and support decision-making for the next part of the educational process, leading to a more effective delivery of the lesson to students (Srivastava, Mishra, & Waghmare, 2018).

Through formative assessment techniques implemented in the classroom, students receive immediate feedback from both teachers and peers, improving both their knowledge and motivation to continue learning. The primary purposes of formative classroom assessments are to check for misconceptions or prior knowledge and gather information about students' prior knowledge (Enerson et al., 2007). Lakshmi and Majid (2019) found that certain classroom assessment techniques, such as the Background Knowledge Probe, The Memory Matrix, and The Misconceptions Check, are effective in assessing cognitive domains following the Bloom taxonomy. Teachers often conduct informal assessments to monitor student behavior, check comprehension, or plan for the next topic (Mertler, 2017). The purpose of classroom assessments is to help students enhance their abilities (Luitel, 2022) and make decisions for the next stages of the instructional process, as well as to support the development of instructional methodologies and the overall improvement of educational institutions (William & Leahy, 2015).

A study by Kaptan and Timurlenk (2012) identified the main challenges facing science education, including a disconnect with other subjects, teaching at an information level, passive students, and active teachers. These factors contribute to a lack of motivation and self-confidence among students. Edwards (2013) suggested that for teachers to be effective in science education, they must understand the areas to focus on to ensure meaningful and helpful evaluation of student knowledge. He proposed a framework for evaluating the quality of scientific research that focuses on five aspects: teaching, students, proof of learning, future decision-making, and impact.

Good teaching practices include high-quality assessment as an essential component (Syarifuddin, 2020). Teachers need to focus on making their assessment of student learning meaningful and useful for ongoing learning and development (Kim, Raza, & Seidman, 2019). This includes considering their assessment practice within the broader context of the learning environment, individual student needs, and continuously improving their assessment skills. Additionally, teachers should collect feedback from students prior to lectures and regularly monitor their learning progress (Tien, Anh, Van Luong, Ngoc, & Vuong, 2020). Given the wide range of content and skills in science, science teachers require extensive and intricate assessment capabilities, requiring specialized knowledge and expertise (Darling-Hammond, Flook, Cook-Harvey, Barron, & Osher, 2020).

This research aimed to conduct a qualitative study using the interview method to gain a deeper understanding of students' views on formative assessment and how it can enhance their learning experience in science. The deeper understanding of students' prowess in subjects would benefit both the teacher and students to design the lessons more efficient, fabricating the students' confidence and develop their sense towards the world around. By conducting semi-structured interviews, the study provided insights into the various aspects of how such evaluations improve the learning experience.

1.1. Conceptual Model

There are many models available for classroom assessment procedures, with many focusing on enhancing the performance of the teacher rather than considering the student's perspective. In a study by Black, Harrison, Osborne, and Duschl (2004) on the assessment of science learning for students aged 14-19, they addressed four main issues within the dimensions of assessment: i) providing evidence for the effectiveness of existing dominant models of assessment in science, ii) the effects of assessment on teaching and learning in science, iii) a comparison of the ways in which school science is currently assessed with models from other subjects and countries, and iv)

providing recommendations for more effective assessment in school science. As shown in Figure 1, that students' learning experience in science subjects can be improved through effective CATs, and that the improvement is largely affected by three main elements: factors, effects and impacts, and feedback. The researcher intends to emphasize the elements of CATs that are related to students' learning experiences.

According to Rosli, Mokhsein, and Suppian (2022) classroom assessments allow teachers to assess students' understanding of the subject matter, as the CATs are easily accessible for teachers to gather feedback from students, which only take a short time to complete. In the meantime, students can self-assess their understanding and knowledge of the topics they have learned.

Considering that CATs provide quick feedback to teachers about the class's level of understanding, the ease of accessibility does impact the students' success in their academic studies. Therefore, teachers should use this information to either move the lesson along quickly or address any confusion that may have arisen, which can greatly improve the overall learning experience for students in science classrooms. It is up to the educators to conduct productive CATs to ensure that the main objective of the assessment is met.

This research established two objectives: (i) to examine students' perspectives on CATs and (ii) to identify students' reasoning on CATs. Examining these research objectives was crucial because it provided educators and students with a deeper understanding of the benefits of implementing Classroom Assessment Techniques (CATs) and how it can bring about significant changes in teaching and learning.

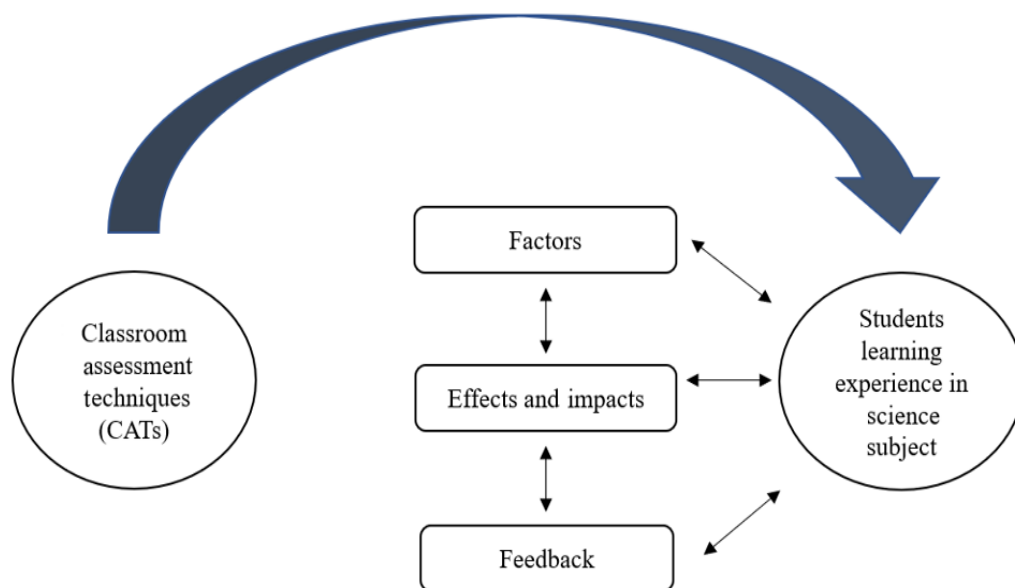


Figure 1. Classroom assessment techniques, students' learning experience and its effects on students.

2. LITERATURE REVIEW

2.1. Classroom Assessment Techniques (CATs)

Teachers can gain valuable insights into their students' learning and development by observing their behavior and collecting feedback from them (Carless, 2020). The term "assessment" encompasses a wide range of instruments or processes that teachers use to monitor their students' progress in learning, skill acquisition, academic demands, and preparedness (Islam & Stapa, 2019). Effective evaluation techniques in the classroom are closely tied to the goals of the lessons being taught and the expected learning outcomes (DiCarlo & Cooper, 2014). Consequently, conducting this type of evaluation in a classroom is crucial to ensuring that students have a solid understanding of the material they are learning (Bergquist & Holbeck, 2014).

Classroom assessment is aimed at helping teachers determine what their students are learning and how they are learning it. Cross and Angelo (1988) defined classroom evaluation as ongoing, context-specific, and grounded in

sound teaching practices. Effective classroom assessments are learner-centered, with the primary focus being on observing and enhancing learning rather than improving instruction. The teacher guides the assessment, determining what to assess, how to assess it, and how to respond to the information gathered.

Classroom Assessment Techniques (CATs) are a form of formative assessment that are not graded and used to evaluate students' knowledge and comprehension. According to [Cross and Palese \(2015\)](#) CATs can take on various forms, some aimed at evaluating students' prior knowledge and others at determining their mastery in areas such as critical thinking.

Regardless of their specific purpose, these techniques aim to gather information about both the students and the teacher and provide feedback to both. The goal of classroom assessment is to improve student learning and should involve both teachers and students, adopting a formative approach rather than a summative one. The purpose is to provide information on student progress and better prepare them for success.

2.2. Types of Classroom Assessment Techniques (CATs)

The use of Classroom Assessment Techniques (CATs) can greatly benefit both teachers and students in the classroom setting. CATs assess students' knowledge, skills, and attitudes related to the course being taught, as well as their response to instruction ([Tabuena, 2019](#)). The results of CATs can be used by instructors to improve their teaching, as the techniques are created, administered, and evaluated by the instructors themselves and address important topics of teaching and learning ([Kucuktepe, 2015](#)).

One such CAT is the Minute Paper, also known as the One-Minute Paper or Half-Sheet Response. This technique provides the instructor with quick and easy feedback on students' learning, as students are asked to write anonymous responses to a specific aspect of the day's class session in 60 seconds ([Kucuktepe, 2015](#)). This technique also helps students recall what they have learned and highlights any gaps between their understanding and the instructor's objectives. Another CAT is the Muddiest Point, which gives immediate feedback on what students find most difficult or confusing during the class ([Enerson et al., 2007](#)). This information can be used by instructors to evaluate which points need to be emphasized more in the future and how much time to spend on a certain topic ([Enerson et al., 2007](#)). Meanwhile, students are challenged to identify what they do not understand and communicate their lack of comprehension ([Marks, 2014](#)).

A technique called One-Sentence Summary technique requires students to condense their answers to questions into a single sentence ([Hanson & Florestano, 2020](#)). This activity allows instructors to evaluate students' comprehension and ability to consolidate information into a form that can be easily processed and recalled ([Marks, 2014](#)). [Benzer, Sefer, Oren, and Konuk \(2016\)](#) believe that having students write summaries helps them determine the main point of the text and recall material. The Student-Generated Questions technique promotes self-regulated learning by shifting the evaluation from the teacher to the students ([Caspari-Sadeghi, Forster-Heinlein, Maegdefrau, & Bachl, 2021](#)). This activity encourages students to engage in deeper and more active learning, and provides a framework for their ideas and comprehension of scientific concepts ([Chin & Brown, 2002](#)). The process of creating questions and answers can help improve students' memory and ability to digest information ([Ebersbach, Feierabend, & Nazari, 2020](#)).

2.3. Positive Impact of Classroom Assessment Techniques (CATs)

[Enerson et al. \(2007\)](#) provided a list of suggestions for using formative assessments to maintain the effective application of classroom assessment techniques (CATs) and to ensure that they provide relevant information. This process can be done on an ongoing basis for pedagogical and instructional purposes in the classroom at the end of each session, at key points in the module, and when evaluating the effectiveness of class activities ([Tabuena, 2019](#)). [Enerson et al. \(2007\)](#) stated that the positive impact of CATs encourages teachers to analyze what occurs in the

classroom and helps students self-analyze their learning. This is a positive implication of CATs because it encourages teachers to objectively analyze their teaching practices.

Wiliam and Leahy (2015) noted that formative assessment can be broken down into five major tactics, including: clarifying and comprehending learning objectives and success criteria, designing effective classroom discussions and activities, giving feedback that advances learning, activating students as instructional resources for one another, and empowering students as owners of their learning. The use of assessment strategies in the classroom can be beneficial for teachers as they provide quick feedback that can help improve both short-term teaching and grading, as well as long-term modifications to the curriculum development (Tabuena, 2019). Most teachers (95%) reported that these strategies led to an improvement in their classroom practice (Wiliam & Leahy, 2015). The use of assessment strategies in the classroom can also help students develop skills in self-evaluation and learning management, reduce feelings of isolation and helplessness, enhance critical thinking skills, and ensure long-term retention of information (Marks, 2014). These benefits are supported by Wiliam and Leahy (2015) as well as a student who commented that "written comments from my teacher help me understand what I did right and wrong, and set targets for me to improve my work and get a better grade".

3. METHODS

3.1. Sample

This study employed a qualitative research method (Almonawer et al., 2023), specifically a structured interview, to investigate the students' perceptions and experiences with formative assessment, particularly Classroom Assessment Techniques (CATs), in enhancing their learning in science. The structured interview allowed the researcher to delve into the respondents' thoughts and emotions regarding assessment methods used in the classroom and gain a comprehensive understanding of their experiences with and without CATs.

The participants of this study were Year 9 students from a private international school who possessed adequate knowledge and experience in science and had been exposed to Classroom Assessment Techniques (CATs) for some period. Informed consent was obtained from the school principal. A total of 15 students participated in the online interview through Google Forms, all of whom were 14 years old and classmates in the 9th year of the same private international school. Of these participants, 7 (46.7%) were male and 8 (53.3%) were female. In terms of ethnicity, 6 (40.0%) were Chinese, 5 (33.3%) were Indian, 3 (20.0%) were Malay, and 1 (6.7%) was a foreign national. For the semi-structured, in-depth interviews, 4 students were selected randomly.

3.2. Interview Protocol

Table 1 presents the full "Interview Protocol" utilized in this study. The research questions (RQs) are displayed along with the list of "interview questions" that the science students (now identified by their respondent names) were required to answer. Before the interview, the respondents were briefly informed about the study and asked about their willingness to participate. After initial discussions, they agreed to respond to all interview questions using the Google form provided by the researcher.

The researcher allowed flexible time for the respondents to answer all questions. The interview question form was made accessible online for 24 hours starting from 2:00 PM on 8th February 2023. The respondents were provided with a link to the Google form to answer the questions. The estimated time for completion was between 20 to 30 minutes.

The answers in the Google form were recorded and automatically emailed to the researcher. The respondents were informed of all processes involved throughout the interview and informed consent was obtained with permission from the students' parents. Confidentiality was strictly maintained during and after the interview session. Table 1 displays the study's interview protocol and the set of 10 questions addressing the research questions of the study.

Table 1. Interview protocol.

No	Research objectives	Research questions	Interview protocol
1	To explore students' perspectives on CATs.	How do the selected CATs aid in the learning of science?	<ul style="list-style-type: none"> • What type of CATs have you ever experienced? • In what ways do CATs aid your science subject learning experience? • Have you noticed any changes in your learning progress before and after using CATs in the science subject? • How do you feel when your teacher asks you to complete CATs? • Do you feel that learning science is improved with this type of simple assessment?
2	To identify students' reasoning on CATs.	How would you compare your learning experience with and without the use of CATs?	<ul style="list-style-type: none"> • Which classroom assessment techniques (CATs) do you prefer the most? Why? • What are your opinions about CATs and the learning experience in the science subject? • How does it make a difference? • Are you able to connect what you have learned in class to your environment through the use of CATs? • It is believed that CATs can reduce feelings of isolation among students. Do you agree and if so, what are your reasons? • Do you agree that teachers should implement this type of activity for every lesson? Why or why not?

3.3. Data Analysis

This study aimed to answer two research questions through the use of narrative and grounded theory analysis. Both methods allowed the researchers to organize, analyze, and interpret the qualitative data collected from the respondents, taking into account the relevant experiences shared by the participants. The researchers combined the salient points from both methods to create coherent and meaningful perspectives based on reliable assessment techniques. An "Interview Protocol" was developed to interview the respondents, consisting of a combination of open-ended and closed-ended questions, with the majority being open-ended. The protocol includes a total of 11 questions addressing both research questions. Manual coding was used to identify similar themes or analytical ideas, despite the time and effort required. The researchers then attempted to identify repeating themes, patterns, and relationships by utilizing techniques such as word/phrase repetition, primary and secondary comparisons, searching for missing information, and identifying metaphors and analogies that may be present. The results were then summarized by linking each of them meaningfully and highlighting the major themes, while noting any contradictions where applicable.

4. RESULTS

4.1. Students' Perspectives on CATs

The general perspectives on Classroom Assessment Techniques (CATs) used in science learning can be categorized into two common themes: i) Ability to relate science to daily life and ii) enhancement of understanding.

4.2. Ability to Relate Science to Daily Life

All four participants concurred that Classroom Assessment Techniques (CATs) did aid them in discovering the connection between what they have learned in class and their daily life. All the participants shared this view. Furthermore, Participant 2 (P2) concurred that Classroom Assessment Techniques (CATs) could stimulate critical thinking and encourage them to think outside the box to find the correlation between the science theory learned and life.

"Classroom Assessment Techniques also able to relate the theory taught in class and my daily life." (P1)

"If the teacher asks me to write an essay, then I'll be able to relate some of the theory learned with my daily life." (P2)

"I think Classroom Assessment Techniques does help me in finding the correlation of science in class and science in my surrounding. As this kind of assessment sparks critical thinking in my brain, I can find a connection between those two." (P3)

"To me, it helps me stimulate critical thinking. We, students, were instructed to do a short summary in a short time, usually one minute. Short time... and essay... It does require my critical thinking to work hard." (P2)

4.3. Enhancement of Understanding

Learning science can be difficult if students do not comprehend what they have learned in class. The participants agreed that practicing CATs helped them to understand science more easily. According to all participants, their understanding and comprehension of science improved when they were able to connect the theory they learned to daily life. The participants also agreed that practicing CATs quickly relieved their confusion.

"When I did these assessments, it made me understand more the topic." (P1)

"...able to make a relation between the theory taught in class and my daily life. This enhances my understanding of the sciences theory more." (P1)

"...I can highlight one by one what I didn't understand in class. And the confusion will be answered by the teacher so the confusion did not accumulate. By using Classroom Assessment Techniques, my confusion always got the answers." (P2)

"Doing those assessments increase students' understanding in learning..." (P3)

4.4. Students' Reasoning on CATs

Based on the students' perspectives discussed in the previous section, their reasoning on the impact of CATs can be grouped into three common themes: i) self-directed learning, ii) aid in memorization, and iii) reduction of feelings of isolation.

4.5. Self-Directed Learning

Participant 1 was not only introduced to CATs in class but also practiced them during her revision. She mentioned that she got confused before seeking help from the teacher. Participant 2 stated that he felt more motivated in studying because he can self-identify which topics to prioritize when he is confused. Similarly, Participant 3 applied CATs during her self-revision and was able to identify her confusion before seeking guidance from the teacher.

"I also practice this at home whenever I do my revision. After I have done my self-study, I will write what I have learned and what I still cannot understand. On the next day, I will bring the paper to my teacher, so I can get the answer." (P1)

"I feel more motivated to study now after practicing Classroom Assessment Techniques. Because I could simply say, I know which part I should focus on more when I highlighted my confusion on paper." (P2)

"Mainly, I can now self-study better. When I applied Classroom Assessment Techniques in my study, whenever I did my revision, I could simply write down and highlight my area of confusion, then seek guidance from the teacher." (P3)

4.6. Aid in Memorization

All participants agreed that practicing CATs in their studies made it easier for them to understand what they have learned, which led to better memorization. They all voiced this opinion.

“When I did these assessments, it made me understand the topic more. So, when I understand the topic well, it doesn't require me a lot to memorize.” (P1)

“When I understand, I think it is easier for me to remember the topic.” (P2)

“Doing those assessments increase students' understanding in learning which will cause students to memorize better.” (P3)

4.7. Reduction of Feelings of Isolation

Participants 2 and 3 concurred that CATs can reduce feelings of isolation among students, particularly introverted students. The anonymity provided by CATs allowed them to ask questions without fear of being judged and without the need to directly speak with the teacher. However, Participant 1 did not comment on this.

“I think that Classroom Assessment Techniques help a lot for introverted students, for a student who is embarrassed to ask their question. By writing on paper, they could get the answer immediately without anyone knowing that is their question.” (P2)

“I agree that Classroom Assessment Techniques could reduce the feeling of isolation in students. In the classroom, there are many types of students. I can see that extroverted students could easily address their confusion or questions directly to the teacher in class. But for some introverts, it may be hard for them to voice their question. So, by writing it on paper, they could simply write and ask the teacher through the paper. Plus, when the teacher answers the student, they may find that other students also have the same question just like them.” (P3).

5. DISCUSSION AND CONCLUSION

All participants believed that CATs stimulated their critical thinking and enabled them to relate the science theory they had learned in class to their surroundings and daily life, thus enhancing their understanding of science. These CATs were meant to help students better memorize the key concepts of what they had learnt throughout the lesson and simultaneously benefited them to identify any gaps or misconception they made. Through repetition, these formative feedback by the students would enable the students to link in between lessons and better develop their understanding in science subject. This was supported by Nappi (2017) who stated that teachers design tasks that challenge students to analyze information through gathering and evaluating data, instead of just memorization and recall of facts, and utilize questioning strategies that allowed students to engage in metacognition. The common themes found in the participants' responses about the impact they experienced after practicing CATs were that the techniques helped them become self-directed learners, improved their memorization, and reduced feelings of isolation during the science lesson. This is supported by a study by Cross and Palese (2015) which found that the formative nature of CATs provided a secure environment where more competent students could mentor less competent peers, assist educators in providing learners with more specialized attention, and increase the amount of interaction between teachers and students.

This study delves deeper into the views, feelings, and experiences of students who have been introduced to and exposed to CATs, seeking to better understand their perspectives in understanding science concept and better explanation after using CATs in their learning process. It is interesting to note that some of the answers, views, and experiences support previous literature findings. Thus, one significant implication of this study can be directly relevant to stakeholders in the educational field especially for science teachers.

It would be beneficial if more schools or other learning institutions were open and willing to let their students participate in a sample of a similar study. Such a study would generate extensive findings and information regarding the views, feelings, and experiences of a larger group of students concerning CATs, creating a greater understanding towards applying CATs more widely. Additionally, since CATs are now being introduced specifically in science lessons, the effectiveness of these techniques must be studied more deeply to assist both the

teachers and students to perform better in science subject. It is hoped that future studies can take note of this and propose improved methods and/or strategies to collect more information. All parties, parents, and science teachers alike, need to be aware and well-informed about students' learning progress under their care. Students often choose to remain quiet about what they do not understand rather than asking for help, perhaps due to their shyness and high expectations of the science teacher. Nowadays, students need to be taught innovative methods of studying to prevent them from losing focus. Science teachers and schools need to be more proactive in this scenario and be prepared to continually adapt to new ways of engaging students. It is essential to create a healthy learning environment for students to have an effective course of action in studying. This may significantly help and improve students' knowledge and learning experience. The role of science teacher is to be an individual who is always eager to help students create a fun and engaging science lesson. By implementing CATs in studying, students could find the learning session less tedious. In addition, students find it exciting to practice independently, which encourages them to be more self-sufficient rather than relying on answers from teachers.

In conclusion, science teachers must play a more dynamic and impactful role as educators in their students' lives. Furthermore, they must be more observant of their students and evaluate their performance and attitudes in class, while also being sensitive to unseen or implicit signs of potential confusion and addressing those issues. As educators, science teachers need to learn and gain more knowledge to strengthen their teaching strategies to make it more impactful. This aligns with the findings by [Opfer and Pedder \(2011\)](#) who stated that prior knowledge greatly influences teacher learning. The interaction of teacher-learning systems results in new information emerging as teachers learn. This new knowledge then recursively influences what is known about teaching and future learning. Insights such as the views and experiences of the participants in this study successfully provide a better understanding of the application of CATs, which is believed to bring more benefits and support students in their studies. This information is relevant and important for stakeholders to recognize and consider. These experiences and the impact of CATs on students can be collected and compiled to serve as a benchmark for other students.

Due to the researcher's choice of an international private school as the study location, the data obtained might not represent the full spectrum of students' views from different backgrounds and school settings. For example, the data gathered in this study may not encompass the perspectives of students from rural schools, who might have different views on applying CATs compared to students in urban areas. Additionally, this study was limited to a specific age group, and the information obtained might differ if other age groups were included in the research. The researcher also hopes that future researchers conducting similar studies will increase the number of participants to include more students at other schools in various geographical locations (urban and rural). It is crucial that all relevant parties collaborate and work to enhance the effect of CATs in positive ways.

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Institutional Review Board Statement: The Ethical Committee of the INTI International University, Malaysia has granted approval for this study (Ref. No. INTI/UEC/2023/007).

Transparency: The authors state that the manuscript is honest, truthful, and transparent, that no key aspects of the investigation have been omitted, and that any differences from the study as planned have been clarified. This study followed all writing ethics.

Competing Interests: The authors declare that they have no competing interests.

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