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Designing a classroom to promote reflective thinking for meaningful learning

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ABSTRACT

This mixed-methods study aimed to ascertain the effectiveness of structured reflective strategies in encouraging reflective thinking in students and promoting meaningful learning. The study employed a pre-post-test quasi-experimental research design. Participants were 56 senior secondary students (25 boys and 31 girls) enrolled in a non-residential, out-of-school science enrichment camp conducted at a private educational institute in a city in Western India. A three-week-long intervention integrating reflective strategies with the experimental science course was implemented during the camp. Quantitative data were collected using a pre-post survey. Qualitative data were captured through students' verbal and written reflections. Analysis of quantitative data using t-tests revealed a substantial increase in participants' reflective thinking and a significant decrease in non-reflection following the intervention. Qualitative data analysis demonstrated a progressive enhancement in participants' understanding, reflection, and critical reflection and a subsequent decrease in mechanical action over time. Furthermore, the participants' reflections revealed that they perceived their learning as meaningful. The findings indicated that the intervention effectively promoted reflective thinking among students and enhanced the meaningfulness of their learning process. The study offers valuable insights for researchers and teachers in designing student-centered environments that foster reflective thinking and meaningful learning.

Contribution/Originality: This study innovatively models an experimental science classroom by systematically integrating a blend of individual and group reflective strategies into classroom practices. This comprehensive approach encourages student reflection and enhances the meaningfulness of students' learning experiences. The study trains teachers with strategies to nurture students' reflective thinking for meaningful learning.

1. INTRODUCTION

Teachers mostly agree that secondary education establishes a foundation for students' affective and cognitive development. However, the greatest concern of teachers is the continued overemphasis on rote learning in instructional and assessment methods in the education system. Mayer (2002) asserted that knowledge acquisition and retention is a restrictive educational goal. Skills related to collecting, storing, and retrieving information are becoming less valued with the rising influence of technology, especially artificial intelligence (AI) tools (Bell, Kelton, McDonagh, Mladenovic, & Morrison, 2011; Chen & Chen, 2022); Muro et al., 2019, as cited in Zhao and Watterston (2021)). Alternatively, scholars advocate the importance of cultivating various high-order thinking

skills essential to thrive in a global landscape (Zhao, Wehmeyer, Basham, & Hansen, 2019). High-order thinking skills empower learners to organize and interpret their ideas and the content being learnt.

Furthermore, it has become increasingly crucial to engage students in meaningful learning. Meaningful learning refers to a learning process that integrates new knowledge with prior understanding (Novak, 2002) allowing the learner to understand, retain, and apply the material in various contexts (Mayer, 2002; Novak, 2002; Sexton, 2020; Zidi, Jalaludin, & Rasul, 2024). Considering its significance, exploring skills and strategies that make learning meaningful is a significant dimension of education (Gentry & Owen, 2004).

Several scholars have highlighted the role of reflective thinking in enhancing the meaningfulness of the learning process (Dkhar & Newmei, 2015; Guthrie & McCracken, 2010; Moon, 1999; Xie, Ke, & Sharma, 2008). Moon (2001) contended that thinking reflectively allows learners to process the learning material and link it to previous ideas. Thus, reflection plays a key role in knowledge construction. Thinking reflectively prompts students to extract inferences and meaning from their learning (Dunlap, 2008; Lin, Hmelo, Kinzer, & Secules, 1999).

Thus, it can be inferred that strategies enhancing reflection in students make learning meaningful for them. Thinking reflectively allows learners to construct knowledge and apply it in different contexts.

2. LITERATURE REVIEW

The notion of reflective thinking was introduced by Dewey as a specialized form of thinking leading to evidence-based learning (Moon, 2001). Since then, a growing body of researchers and teachers has highlighted the instrumental role of reflective thinking in gaining insights from experience (Boud, Keogh, & Walker, 2013; Daudelin, 1996; Kolb, 1984). Furthermore, several researchers posit that reflection encourages learners to derive meaning during the learning experience and thereby facilitates a deep approach to learning (Coulson & Harvey, 2013; Leung & Kember, 2003; Moon, 2001; Rodgers, 2002).

Although scholars lack consensus on whether reflective thinking is innate or an acquired skill, a majority of them agree that it can be encouraged through the use of scientific methods (Coulson & Harvey, 2013; Gelter, 2003; Moon, 2001, 2007). Most of the researchers agree that reflective thinking progresses through stages showing increasing depth and complexity. Several scholars have proposed pyramidal models of reflection based on this progression in the extent of reflection (Kember et al., 2000; Kitchenham, 2008; Taggart & Wilson, 1996; Van Manen, 1977).

Furthermore, numerous strategies have been reported to promote student reflection in academic settings. Teaching-learning strategies popularly known to encourage students to reflect are journaling, question prompts, peer feedback, questioning and wait time (Bell et al., 2011; Chen & Chen, 2022; Guthrie & McCracken, 2010; Song, Koszalka, & Grabowski, 2005). The most popular reflective strategy is journaling (Moon, 2007). Apart from prompting reflection on experience, it also allows teachers to evaluate the extent of students' reflective thinking (Kember, McKay, Sinclair, & Wong, 2008).

Another significant factor that contributes to developing thinking skills in students is the learning environment. The problem-based learning environment has been demonstrated to provide an unstructured and learner-centric classroom environment that urges students to think reflectively (Song et al., 2005). Reflective strategies have been integrated with virtual learning environments and flipped learning environments to foster reflective thinking (Chen, Hwang, & Chang, 2019; Guthrie & McCracken, 2010, 2014).

Interestingly, exploration of the literature on empirical studies evaluating interventions to enhance students' reflective thinking revealed contradictory findings. Chen et al. (2019) reported that integrating reflective strategies in flipped classroom revealed significant improvement in students' reflective thinking. A few other studies have reported a significant enhancement in reflective thinking levels after an intervention (Eğmir & Gürbüz, 2018; Kaplan, Doruk, & Öztürk, 2017). Most of these studies were conducted in problem-based learning environments and technology-based environments. On the contrary, several researchers reported that the increase was not

statistically significant although there was an increase in students' reflection levels following an intervention (Antonio, 2020; Cisero, 2006). These non-significant results could be attributed to several factors. Learning to reflect is a gradual process and the progress of any student is on an individual continuum. Hence, the results will depend upon the duration and intensity of the intervention. Secondly, the inappropriateness of the reflective strategy for the age group may affect the process. Similarly, most of the interventions use a single reflective strategy such as reflective journaling or use of reflection prompts. These strategies may not be suitable for all students.

The present study aimed at designing the classroom environment using a combination of reflective strategies in a systematic and organized manner to promote reflective thinking of students and make learning meaningful for them. The study was conducted in science laboratory settings.

3. THEORETICAL FRAMEWORK FOR MEASURING REFLECTIVE THINKING

The model of "levels of reflection" outlined by Kember et al. (2000) served as the framework for assessing the increase in participants' reflective thinking. These levels outlined in the model are habitual action, understanding, reflection, and critical reflection (Kember et al., 2000). Habitual or mechanical actions are actions without any conscious thoughts about what one is doing whereas understanding refers to thorough comprehension of theoretical concepts without relating it to other learning (Bermúdez & Felletti, 2021). Habitual action and understanding represent non-reflection. Reflection involves engaging in cognitive and affective activities that leads to new insights and deeper appreciation (Rodgers, 2002). Critical reflection is the highest level of reflection that leads to perspective transformation (Kember et al., 2000).

4. PURPOSE OF THE STUDY

The purpose of this research was to determine if using structured reflective strategies- a systematic approach to using a combination of reflective strategies, can promote reflective thinking in students. Systematic use of reflective strategies over time was expected to reduce habitual action and increase understanding, reflection, and critical reflection. Furthermore, researchers sought to determine if fostering reflective thinking leads to meaningful learning. The research objectives of this study were as follows:

1. To determine the effectiveness of structured reflective strategies in reducing habitual action in students
2. To analyze the effectiveness of structured reflective strategies in promoting students' understanding, reflection, and critical reflection.
3. To identify the student's perceptions of the impact of reflective strategies on making their learning meaningful

The following research hypotheses were proposed:

H_1: The intervention based on integrating structured reflective strategies into science experiments significantly decreases 'habitual action' in students.

H_2: The intervention based on integrating structured reflective strategies into science experiments significantly increases 'understanding', 'reflection', and 'critical reflection' in students.

5. METHODOLOGY

5.1. Context

The study was undertaken during an out-of-school, non-residential science camp in a midsized city in western India. The science camp was an enrichment program organized by Learners' Academy (LearnAc), a private institute that offers both after-school and summer enrichment programs. The summer science camp enrolls children from grades 9 to 12. Each student attends the camp for 3 days per week over 3 weeks. The participants are organized into groups; Level I, comprising students in grades 9 and 10, and level II comprising students in grades 11 and 12.

Each group completes a total of 9 with each session lasting 5 hours (including a lunch break of 45 minutes). The program provides students with the opportunity to work in well-equipped science laboratories. Students are engaged in hands-on experimentation in teacher-allotted peer groups. The content covered provides enrichment opportunities for students who are interested in science. However, there is no selection test for enrolment in the camp.

5.2. Participants

The study was conducted on students enrolled for level II of the out-of-school, non-residential science summer camp. A total of 56 participants (ages 15–17; 25 boys and 31 girls) from eight different English-medium schools in the city participated in the study. Out of the 56 participants, 12 (5 boys) were studying in grade 11 and 44 (20 boys) in grade 12 at the time of data collection. Participants came from middle-income and high-income backgrounds. Figure 1 displays student distribution by gender and grade.

56 participants were randomly divided into 3 cohorts. Each cohort attended the sessions on different days. They performed the experiments in smaller groups of 5-6 students.

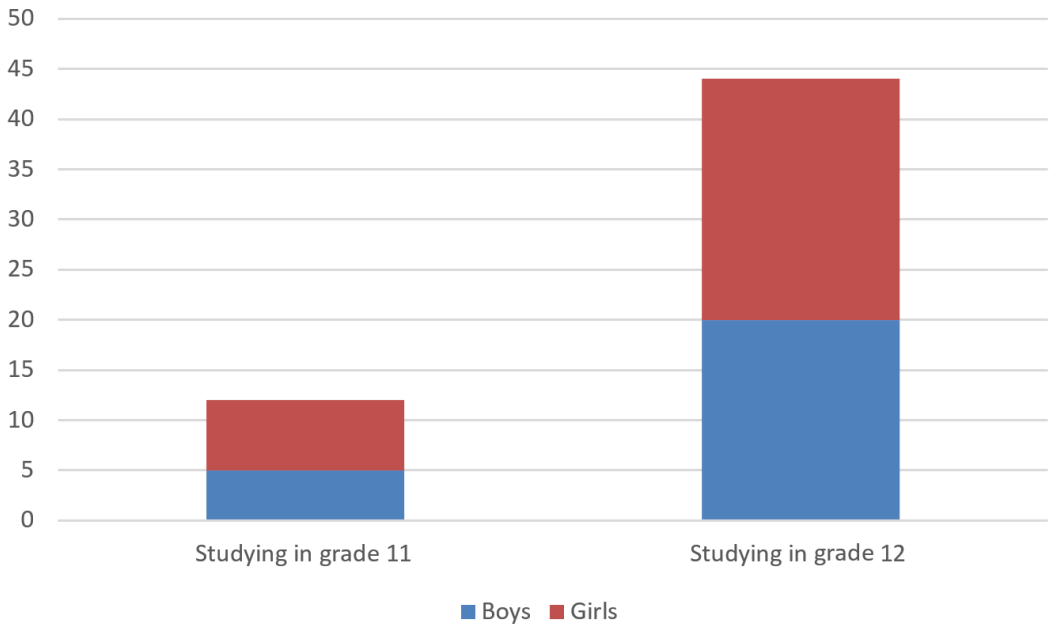

Figure 1. Student distribution by gender and grade.

5.3. Instrument

The Reflective Thinking Questionnaire (RTQ) developed by Kember et al. (2000) was used to collect the quantitative data (see Appendix 1).

The tool measures the extent of student engagement in reflective thinking. RTQ is a 16-item questionnaire using a Likert-type scale from 1 (*strongly disagree*) to 5 (*strongly agree*). The 16 items are divided into 4 constructs such as habitual action (HA), understanding (U), reflection (R), and critical reflection (CR). RTQ shows robust psychometric properties, including construct validity and satisfactory internal consistency. Confirmatory factor analysis indicates a good fit for the intended four-factor structure (Kember et al., 2000). The authors recommend the use of the tool in academic programs across domains.

5.4. Structured Reflective Strategies used in the Study

Individual as well as group reflective strategies were used to encourage students' reflective thinking. The four reflective strategies used during each session are described below.

Reflective questioning and wait time: Reflective questioning is a strategy commonly used by teachers at the beginning of a class to encourage reflection on previous knowledge (Van Es, 2006). Allowing an appropriate amount of wait time after posing a question encourages deeper thinking and thoughtful responses (Rowe, 1986; Van Es, 2006). It also encourages various students to answer. The duration of wait time will depend upon the complexity of the question (Van Es, 2006).

At the beginning of each experimental session, the teacher posed questions to elicit answers based on previous knowledge. After asking the question, the students were told to wait for a minimum of 30 seconds before responding to get more thoughtful answers. It also ensured maximum participation.

Pause and think time: Pause and think time refers to specific periods of silence during an activity wherein both teacher and students think quietly (Rowe, 1986; Stahl, 1994). This intermittent pause time during an activity enables students to step back and reflect on their actions and feelings. Similarly, it reduces the stress of end-to-end tasks. Providing students with specific question prompts during the pause and think time increases the chances of a deeper analysis of the experience and feelings (Song et al., 2005).

During the 3-hour experimental session, the students were given 3 minutes of "pause and think" time twice. During this time, the students were encouraged to sit quietly and ponder on their experiences, learnings, and feelings and write them down on a piece of paper. The students had a choice to attach the paper to their reflective journal or keep it to themselves. The idea was to help them compose their thoughts without the anxiety of exposing themselves to others or the facilitator (Moon, 2001). The data collected were not analyzed as the participants had an option to submit the data.

Reflective debriefing: Reflective debriefing is a strategy where students can evaluate the experience in a group. Reflective debriefing gives a person a fresh perspective on an experience that wouldn't be possible through individual/ solitary reflection. It also provides students a chance to iterate.

The teacher conducted a debriefing for 10-15 minutes at the end of each session. This allowed the students to reflect on their experiences during the session. The teacher initiated the group discussion. A pedagogy expert took on the role of a neutral observer and recorded the summary of responses. The question prompts that guided the reflective debriefing were as follows:

- What did you learn?

  Follow-up question: Did you learn any new skills?
- Where can you apply what you have learnt today?

  Follow-up questions were as follows: Can you use it in daily life?
- What did you like about the session?
- What was your experience of working in groups?

  Follow-up questions: Did you enjoy group work? Did you find it challenging? Why?
- What aspect of the session did you find challenging?
- How did you overcome the challenge?
- What would you do differently in the next session?

Reflective Journals – daily reflections: Reflective journals allow students to reflect and process their understanding and perspectives on classroom interactions and aid teachers in gaining valuable insights into the learning process and learning outcomes (Cisero, 2006).

Students had to write reflections about the sessions in a journal after each session as a home assignment. Question prompts given to guide them in writing their reflections were the same as those in reflective debriefing. However, writing journals gave students an opportunity to express their thoughts privately typically those that were not shared verbally during reflective debriefing.

Reflective Journals – summative feedback: Additionally, during the last session, students were asked to write summative feedback for the program. The reflective prompts that were given as a framework to guide the students were:

- What are your learnings from the program?
- Did the reflective strategies used during the sessions (questioning, pause and think time, reflective debriefing and reflective journaling) help your learning process? Elaborate your answer.
- What challenges did you face? How did you overcome them?
- Do you notice any change in yourself after attending this program?
- Which aspect of the program needs to be changed according to you?

5.5. Research Design

A convergent parallel mixed-methods research design was used to maximize the merits of quantitative and qualitative data analyses (Creswell & Clark, 2017). Quantitative data were collected using a survey and the qualitative data were collected through students' verbal and written reflections. Ultimately, the results were triangulated to present a holistic picture of the effect of the intervention on students' reflective thinking.

5.6. Procedure

The participants and their parents were briefed about the study at the time of enrolment for the science camp. Consent was taken from the participants' parents for using the data for study purposes and confidentiality was assured. Each participant was assigned a unique code number by the school psychologist to ensure anonymity. On the first day of the camp, all the participants responded to the RTQ (pre-test). Demographic data of the participants was collected on a separate sheet. The intervention was implemented for nine laboratory sessions over 3 weeks. Participants wrote reflective journals as a home assignment after each session. On the final day of the camp, the participants responded to RTQ (post-test) again. They also wrote summative feedback about their experiences during the intervention.

5.7. Data Collection

Quantitative data were collected using the Reflective Thinking Questionnaire (RTQ) developed by Kember et al. (2000). RTQ was administered collectively to all the students as a pre-test before the commencement of the science experiment sessions and then again as a post-test after all the sessions were completed.

Qualitative data were captured using neutral observer's notes of the reflective debriefing, daily reflective journals, and summative feedback. Thus, the data were collected at different points of the program and using different methods.

5.8. Data Analysis

Quantitative data collected using RTQ were analyzed using version 25 of the Statistical Package for Social Sciences (SPSS). A matched sample t-test was conducted to determine whether there was any change in the mean scores of the reflective thinking levels between pretest and posttest.

Qualitative data obtained by different means, namely daily reflections, summative feedback, and neutral observer's notes, were analyzed deductively. Initially, the first and the second authors read the responses thoroughly to familiarize themselves with the data. Next, the researchers highlighted the excerpts of the data that were relevant to the study. Then the highlighted responses were coded deductively under four categories, namely, habitual action, understanding, reflection, and critical reflection as per the coding scheme provided by Kember et al. (2008). These categories represented the main themes. A detailed description of the four categories is provided in Table 1. Apart from this, excerpts suggesting meaningful learning were coded under a separate theme.

Additionally, the two researchers completed peer debriefing with the third author in which they reviewed the coding for a small portion of the data (one excerpt under each theme). Necessary changes were made to improve the coding accuracy. Subsequently, the first two authors reviewed the coding for the entire data corpus till they achieved a consensus. Finally, they identified sub-themes under each theme and categorized the data under the sub-themes. As a final audit check, the entire coding was reviewed by the third author. The findings were lastly shown to the neutral observer who had witnessed all the sessions for member checking. The final report has been presented in the subsequent section.

Table 1. Descriptors of themes adapted from the four-category coding scheme.

Themes	Descriptors
Habitual action (HA)	• Experiments are performed as per the demonstration given by the teacher or by following the steps in the laboratory manual. • No attempt is made to interpret the procedure or understand the principle behind the experiment or the underpinning theory. • Written matter is copied from some source without thinking about it or without real understanding. • Instructions given by others are followed unquestioningly or without any thought. • Views put forth by others are accepted without proper comprehension or evaluation.
Understanding (U)	• Student comprehends the concept or theory behind the experiment. • There is a correct explanation of theory without any consideration of how the concept is related to practical/ Real-life situations or personal experiences.
Reflection (R)	• Experiment performed or concept taught is related to previous knowledge or knowledge from other domains. • Attempt is made to relate the classroom or laboratory learning to practical or real-life situations or personal experience. • Personal insight is seen in the written work. • Evaluate what one reads or is told by others.
Critical reflection (CR)	• Evidence of change in view over the understanding of a key concept or phenomenon. • Evidence of critical review and transformation of deep-seated beliefs /Values/ Presumptions/Attitudes based on new evidence

Source: Kember et al. (2008).

Trustworthiness: The researcher undertook several measures to ensure the trustworthiness of the qualitative analysis.

An audit check was ensured throughout the study. The data were analyzed collaboratively by at least two researchers at each stage.

Additionally, the third author, not involved in the initial data analysis process, was involved in peer debriefing, and the final review of the codes, themes, and sub-themes.

Moreover, the first author has been a senior facilitator at the science camp for the past three years and is familiar with the program. All the above measures along with member checking and the researcher's reflections enhanced the credibility of the study.

Furthermore, this article gives a detailed description of the settings, participants, and time frame for data collection to facilitate the transferability of the qualitative findings to a different context. Additionally, the detailed description of the data analysis process and the participant quotes (see Table 3) ensure transparency of the study.

6. RESULTS

6.1. Inferential Statistics

A matched sample t-test was conducted to determine whether there was a change in students' reflective thinking levels post-intervention. The results demonstrated a significant decrease in habitual action post-intervention. Therefore, hypothesis 1, which proposed "the intervention based on integrating structured reflective strategies into science experiments significantly decreases habitual action in students" was accepted. There was a significant increase in understanding, reflection, and critical reflection post-intervention. This supports hypothesis 2, which proposed that "the intervention based on integrating structured reflective strategies into science experiments significantly increases understanding and reflection, in students". The results are displayed in Table 2.

Table 2. Matched sample t-test results comparing pre-test and post-test scores for HA, U, R, and CR. (n=56).

Factors	Pretest	Post-test	t – value	p-value
	Mean ± S.D			
Habitual action (HA)	4.1875 ± 0.394	3.2589± 0.448	10.555	0.000***
Understanding (U)	3.0982± 0. 398	4.0714± 0. 6194	-9.994	0.000***
Reflection (R)	3.1384± 0. 482	4.0402± 0. 518	-9.776	0.000***
Critical reflection (CR)	2.7188± 0. 364	3.4018± 0. 545	-9.571	0.000***

Note: ***p<0.001.

6.2. Qualitative Findings

Students' reflections were analyzed to determine the level at which they reflected and to understand their perception of the impact of reflection on their learning process. It was noted that answers to question prompts during initial sessions were mostly cursory. The written matter also didn't show any depth. The responses became increasingly thoughtful as the sessions progressed, offering valuable insight into the respondents' thought processes.

The themes and sub-themes have been presented subsequently. The illustrative/notable quotes under each theme have been presented in Table 3.

Theme I: Habitual action.

Sub-theme I a: Rote learning.

In the initial sessions, when the students were asked questions about previous knowledge, their answers were primarily based on recall. They could reproduce the definitions learnt in prior classes. However, they couldn't explain their answers when asked to do so. The answers were superficial and based on memory and not understanding. In response to the question prompt, "What did you learn today?" The students narrated the tasks performed with little thought as to why they did it. For instance, a student wrote. *"I learnt to prepare slides of pollen germination."* Another wrote, *"I did an experiment to find the speed of sound in air at room temperature using a resonance tube by two resonance positions."* A few students reported that since they were well-versed in the experimental procedure, they didn't have to think much about it.

Sub-theme I b: Uncritical obedience.

Written reflections of the first few sessions indicate that the students mainly relied on the instructions given by the teacher. A task was done in a particular way because the teacher had instructed them to do so. A participant commented, *"I saw the teacher take the transverse sections. I did as shown by the teacher and got good sections."* The comments suggested that the students believed that they could perform tasks correctly only by following the teachers' instructions to the minutest detail. There was an uncritical acceptance of the teacher's views.

Theme II: Understanding.

When answering the question, What did you learn? The students mostly described the theoretical concept underlying the experiment. Their answer indicated that they comprehended the concepts with clarity. However, there was no attempt to relate it to other learnings or explain it out of academic context. The students could

explain the concepts learnt in prior classes even when recalling the previous knowledge. However, there was no evidence of applying it to the experiment. After preparing a mitosis slide, in response to the question, what did you learn? A participant wrote, *"When preparing a mitosis slide, I learnt that the dividing cells expanded when the slide was warmed. The cytoplasm became rare (expansion of fluid) due to heating. Therefore, the cells became large."*

Theme III: Reflection.

With progressing sessions, both verbal and written reflections suggested that the participants were attempting to analyze their learnings, actions, and feelings. They increasingly showed better self and social awareness. The researchers identified 4 sub-themes related to reflection, namely, evaluation of experiences, evaluation of feelings and emotions, application of theory to real-life situations, and relating past knowledge to present experience.

Sub-theme III a: Evaluation of experiences.

Participants reviewed their experiences, commented on the successes and challenges, and identified the areas needing improvement. A participant reported that *"the way of doing the experiments in camp made us think independently. It was challenging. We were not used to setting up experiments independently. We fumbled a lot but then got the hang of it."* Another wrote, *"The science camp gave me a chance to do the experiments without the teacher's continuous instructions. We learnt to work in groups. We supported one another. Rather than crib about what went wrong, we started to think about ways of improving."* They also analyzed their behavior in any situation and developed a better understanding of self. This can be understood well by the comment, *"I realized whenever I see something, I understand it better than when I just read it or the teacher explains."*

Sub-theme III b: Evaluation of feelings and emotions.

Participants often commented on their feelings and emotions in a situation. They were aware of their emotions, analyzed them, and were willing to make the necessary improvements. For example, a student wrote, *"Many times I don't answer because I don't want to feel embarrassed by giving wrong answers. This is something I want to change next time. I hope I have enough courage to do it."* Another commented, *"I am not sure if I want to write everything down in reflective journal. I don't want people, even teacher to know my inner thoughts. I am not comfortable with it. I don't want any criticism."*

Sub-theme III c: Relating past knowledge to present experience.

The students could relate the theory learnt in previous classes to the experiment at hand. For example, a student wrote, *"I had studied phases of mitosis in school. I think when I was in 9th grade. It helped me identify the phases today. I could remember the changes and how chromosomes look in each of the phases. So, I could identify both metaphase and anaphase from the slide that I made."* Most students reported that the questions asked at the beginning of the class not only helped them recall the theory they had learnt but also assisted them while experimenting. A participant mentioned, *"Ma'am (teacher) asked questions on normality and molarity of the solution. I found it difficult. But when a few other students answered, I could remember. Then, when we prepared 1N HCl solution for the practical (experiment) that knowledge came in handy."* A few commented that in response to the question, what would you do differently in the next session? They had written about the mistake they would avoid. During a similar procedure in subsequent sessions, they recalled it and succeeded in avoiding the mistake. Here is a representative quote, *"In the first session, I didn't get the slide correct as I kept taking the sections without keeping a watch on the cut edge of the stem. So, they (stem sections) all came out oblique. I wrote that I will avoid this next time in the journal. I remembered it and this time I took care to avoid the mistake. So, I got proper transverse sections."*

Sub-theme III d: Application of theory to real-life situations.

Several participants attempted to relate the present learnings to practical situations or personal experiences. Notable quotes include *"As we discussed the benefits of hybridization, I wondered if hybrid fruits and vegetables are developed to enhance the quality, why do we still want to buy non-hybrid (gavran) vegetables."*, *"We identified the xerophytic adaptations from the samples (given set of plants). I wonder if we could grow these plants in wastelands where water is scarce. This will slowly increase the water holding capacity of soil in a few years"*.

Theme IV: Critical Reflection.

This is the highest level of reflection wherein there is a critical review of assumptions, attitudes, views, or beliefs leading to their transformation. Views are shaped based on evidence. The summative reflections particularly show notable examples of critical reflection. Two sub-themes were identified related to critical reflection, namely, perspective transformation and attitude transformation.

Sub-theme IV a: Perspective transformation.

Most of the participants reported that group work and reflective debriefing exposed them to diverse perspectives and on several occasions made them rethink their stance. A participant commented, *"One of the coolest guys in the group could do the experiment better than us. We discussed this during debriefing. I always thought that worrying a little is ok. It makes me competitive. But after the discussion I concluded that stress many times makes people loose cool and make more mistakes."* Another participant wrote in the summative reflections, *"I always found it difficult to express my thoughts as I didn't want to make a fool of myself. This camp made me realize that it is not important to keep worrying about what people will think. Maybe people will not judge but give support."*

Sub-theme IV b: Attitude transformation.

Several participants reported that attending the camp brought about a change in their attitude. A participant mentioned, *"First I didn't want to write a reflective journal. I found it boring. I just kept writing it as it was a compulsory part of this camp. Slowly, I realized that it is like a record of all that I have learnt. It makes me understand what I think and all…. So, I started pretty much enjoying it."*

Theme V: Meaningful learning.

As the sessions progressed, students gradually related their present experiences to past knowledge and exhibited deeper comprehension of the concepts being learnt. Furthermore, they explored applications of academic learning. This was suggestive of meaningful learning (Mayer, 2002; Novak, 2002; Sexton, 2020). A participant wrote, *"The pollens didn't germinate in glucose solution. I think maybe the glucose used by us was toxic for pollens. I remember, the chemistry teacher has told that glucose is generally not used for experimentation. It is toxic for organisms unless produced cellularly. That too needs to be converted quickly"*. In this example, the participant could relate the knowledge gained in a chemistry class to the biology experiment being performed.

Table 3. Illustrative quotes.

Themes and Sub-themes	Participant quotes
Habitual action (HA)	
Rote learning	I learnt titration. I learnt to prepare slides.
Uncritical obedience	I got results quickly. In school, I have done titration. Our chemistry teacher told to stop adding solution from the burette the moment the color of the solution in the flask becomes pink. So, I did it accurately and got correct results.
Understanding (U)	Hybridization is done to combine the good characters of two plants. It is a very commonly practiced method of plant breeding. In food crops hybridization is mainly done to improve yield.
Reflection (R)	
Evaluation of experience	We were not used to group work. So, it is chaotic. Everyone tries to answer at the same time. It would be best if next time we laid down a few rules from the beginning. The pause and think time gave me time to think about what we were doing. It gave me breathing time. I realized what I was doing wrong and must change.
Evaluation of feelings and emotions	I was upset when I didn't know the correct answers. Now I think it was more because I was worried that others would label me as dumb. We had the freedom to plan the procedure. This was challenging but lots of fun. I was excited by the challenge.
Relating past knowledge to present experience	We had learnt that impurities in water decrease its boiling point. Hence, we decided to test the boiling point of the water sample to test its purity.
Application of theory to real life	It was so sad to see the toxicity of the water in which "nirmalya" (the stale remains of flowers offered to a deity) was dumped. This may be because like any organic matter the flowers degrade partially and make the water highly acidic. This acidic blog must have promoted the growth of desmids making the water

Themes and Sub-themes	Participant quotes
	toxic.
Critical reflection (CR)	
Perspective transformation	I tend to answer questions as soon as the teacher asks questions. I always thought that it was smart to answer in class. I was appreciated by my friends for it. Now I think that it is better to listen to others first, their views. Then answer thoughtfully.
Attitude transformation	I used to jump to conclusions quickly and then stick to that. I realized this during reflective discussion. I decided to change this. Now I try to find reasons before reaching any conclusion. I listen to ideas given by others.
Meaningful learning	We had learnt the Tyndall effect in chemistry. One boy in the group remembered it. We discussed methods to find out if particulate pollutants are present in water using the Tyndall effect. It took time to set up the experiment. But in the end, we did it. I like the problem-solving cycle that we used during the practical (experiment) today. Once I wrote about what I know and what we need to know etc. in the cycle it became more systematic. Confusion became less. This is a useful trick. I can use this for any problem in life. Not just in class.

7. DISCUSSION

The present study explored whether a science classroom designed to integrate structured reflective strategies with experimental science sessions promotes reflective thinking in students, making their learning meaningful. There was consistency in identifying reflective thinking levels across both approaches and facilitating the triangulation of results since both qualitative and quantitative data were analyzed using the same model of reflective thinking levels proposed by the lead author.

The RTQ pre- and post-test revealed a significant increase in the student's reflective thinking. The results showed an increase in conceptual understanding reflection and critical reflection. Subsequently, there was a notable decrease in habitual action. These findings resonate with previous research wherein the use of specific pedagogies has increased students' reflective thinking (Chen et al., 2019; Eğmir & Gürbüz, 2018; Kaplan et al., 2017).

Students' verbal and written reflections indicated progressive enhancement in their reflective thinking skills. The students focused on technical details and narrated the activities during the sessions without analyzing their experiences consistent with the findings of Beavers, Orange, and Kirkwood (2017) during the initial sessions. The responses to most of the reflective prompts were superficial. Similarly, they remembered the scientific facts but were unable to relate them to practical experiments being performed. Furthermore, they struggled to understand the real-world applications of classroom learning.

Students gradually began to think reflectively as the sessions progressed following the systematic use of reflective strategies and insightful questioning by the teacher throughout the sessions. The verbal group reflections during reflective debriefing provided the students with an opportunity to understand and learn from diverse perspectives about similar experiences during the sessions. This aligns with the findings of Topping (2005) who highlighted the affective as well as cognitive benefits of peer learning. Reflective journal writing provided an avenue to express thoughts privately to those hesitant to share their opinion or perceptions openly in a group.

The descriptive reflections demonstrated that as the students engaged in active reflection on their learning process; they were encouraged to think scientifically. Several students wrote at length about their learning from the science camp in the summative reflective feedback. Additionally, some students described how they would apply the knowledge gained during the camp in other academic areas and in practical life. This concurs with the views put forth by Dunlap, Sobel, and Sands (2007) and Lin et al. (1999). They propounded that reflective activities encourage students to derive meaning from their learning experiences, thereby leading to their personal growth and development. Students' reflections demonstrated that as their reflective thinking deepened, their learning became progressively meaningful. They related knowledge acquired in previous classes or different domains to the present learning. They also deliberated on the practical use of their classroom learning. This aligned with the

definition of meaningful learning proposed by Mayer (2002) who argued that the learner's ability to transfer the acquired knowledge to new situations is indicative of meaningful learning. Thus, it can be inferred that enhancement in reflective thinking also promoted meaningful learning in the students.

7.1. Limitations

This study was conducted out of school science program. Unlike the school curriculum, which is governed by a regulatory body, the camp's curriculum allowed greater flexibility in integrating reflective strategies. Similarly, writing reflective journals was an integral feature of the program. Hence, the researchers suggest caution in generalizing these findings to science courses incorporating reflective strategies within a school set-up.

7.2. Implications and Future Directions

The findings of this study offer valuable insights for researchers and teachers interested in encouraging reflective thinking in students to make their learning experience meaningful. Our results show that employing a robust and methodical approach to implement reflective strategies promotes students' reflective thinking in a relatively short duration. The study presents a structured framework teachers can use to guide students in reflective journaling or facilitating reflective discussions. It may be interesting to conduct a follow-up survey to investigate whether the participants valued the self-reported benefits of writing reflective journals sufficiently to sustain the habit. Moreover, future studies could explore the effectiveness of diverse combinations of structured reflective strategies in school settings.

8. CONCLUSION

The study was conducted during a science camp over 3 weeks. Structured reflective strategies were integrated with the laboratory-based experimental science sessions. The experiments were conducted in an active, student-centered, and collaborative learning environment. The students were engaged in verbal and written reflective activities during and after the experimental sessions. They reflected individually as well as in groups. Data associated with measurable reflective thinking skills indicated a significant increase in understanding, reflection, and critical reflection. Simultaneously, a significant decrease in habitual action was noted. Analysis of the verbal and written reflections using the coding scheme by Kember et al. (2008) also revealed a progressive enhancement in understanding, reflection, and critical reflection levels and a subsequent decrease in habitual action. The students' reflections indicated that thinking reflectively infused meaning into their learning experiences. Thus, it can be affirmed that using a combination of reflective strategies in a methodical and well-organized approach promotes reflective thinking in students and encourages them to derive meaning from their learning experiences.

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Institutional Review Board Statement: The Ethical Committee of the Symbiosis International (Deemed University), India has granted approval for this study on 27 August 2020 (Ref. No. SIU/IEC/175).
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Appendix 1. Reflective thinking questionnaire.

1. When I am working on some activities, I can do them without thinking about what I am doing.
2. This course requires us to understand concepts taught by the lecturer.
3. I sometimes think of better ways to do the activities than the way being demonstrated.
4. As a result of this course, I have changed the way I look at myself.
5. In this course, we do things so many times that I started doing them without thinking about it.
6. To pass this course you need to understand the content.
7. I like to think over what I have been doing and consider alternative ways of doing it.
8. This course has challenged some of my firmly held ideas.
9. As long as I remember the protocol given in the practical handbook, I do not have to think too much before doing the activities myself.
10. I need to understand the material taught by the teacher in order to perform practical tasks.
11. I often reflect on my actions to see whether I could have improved on what I did.
12. As a result of this course, I have changed my normal way of doing things.
13. If I follow what the lecturer says, I do not have to think too much on this course.
14. In this course, you have to continually think about the material you are being taught.
15. I often re-appraise my experience so I can learn from it and improve for my next performance.
16. During this course, I discovered faults in what I had previously believed to be right.

(Items 1,5,9,13 indicate habitual action; items 2,6,10,14 indicate understanding; items 3,7,11,15 indicate reflection; items 4,8,12,16 indicate critical reflection. The authors have allowed the use of the questionnaire after due acknowledgment).

Source: Kember et al. (2000).