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Empowering Science Education: Unveiling the Potential of Advance Organisers in Fostering Science Process Skills within Cooperative Learning Environments

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Abstract

The study explored the effects of incorporating advance organisers within a cooperative learning framework on the acquisition and development of science process skills among students in Integrated Science education at Adugyama Senior High School in the Ashanti Region of Ghana. The study employed a one-group pre-test and post-test design combined with observational qualitative methods. Convenience sampling was utilised to select a sample of the General Art Form 3 class, made up of 44 students. The instruments used to collect data were a class observation checklist, students' records in assessment, and a scoring rubric. The collected data were analysed qualitatively and quantitatively using descriptive statistics and paired samples t-test. The findings revealed remarkable efficacy, indicating that the cooperative learning framework integrated with advance organisers enhanced students' engagement, facilitated the acquisition and demonstration of science process skills, and triggered substantial and noteworthy improvements in the development of these vital skills among learners. Educators are therefore recommended to adopt the advance organiser and cooperative learning strategy to foster students' skill acquisition and development in science education.

Keywords: advance organisers; cooperative learning; science process skills; integrated science education

Introduction

The effectiveness of teaching strategies employed in science education has a profound impact on student achievement (Baafi, 2020). This is particularly evident in the realm of Integrated Science, where students are expected to not only grasp scientific content but also develop essential process skills. These skills, which are commonly known as science process skills and are the building blocks of scientific literacy, aid students to easily understand concept through observation, experimentation, data interpretation, and problem-solving (Ongowo & Indoshi, 2013; Inayah et al., 2020). It is vital for students to be provided with these essential scientific skills at every educational institution since these skills form the foundation for the scientific inquiry (Kamba et al., 2018; Colley, 2006).

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Science process skills are skills individuals can use in each stage of life by being scientifically literate, increasing their quality and standard of life as they understand the nature of science (Aktamis & Ergin, 2008). These skills, according to Apeadido et al. (2024), Kusuma and Rusmansyah (2021) and Prayitno et al. (2017), are categorised as basic process skills and integrated process skills. The basic process skills are simple skills that provide a foundation for the learning of the integrated or complex process skills (Padilla, 2018). These skills include observing, inferring, measuring, communicating, classifying, and predicting (Padilla, 2018; Kusuma & Rusmansyah, 2021). Integrated process skills, on other hand, are complex skills that involve the combination of basic process skills to study or investigate phenomena (Ongowo & Indoshi, 2013; Kusuma & Rusmansyah, 2021). These skills include defining operationally, formulating of hypotheses, controlling variables, formulating models, experimenting, and interpreting data (Kusuma & Rusmansyah, 2021; Saat, 2004; Padilla, 2018). According to Colley (2006), when scientists design and carry out experiments in everyday life, they integrate various basic skills together. Science process skills are integral and natural to a scientist because they are instruments for the study and generation of scientific knowledge. They are required by students to construct knowledge in order to solve problems and formulate results (Ongowo & Indoshi, 2013). Hence, initiatives are required to help students develop their science process skills, such as through utilising effective learning techniques (Inayah et al., 2020).

However, at Adugyama Senior High School in the Ashanti Region of Ghana, a concerning trend of students' suboptimal performance in Integrated Science tests of practical work has been identified through direct observation of the students' performance during practical tasks and analysis of their assessment records. An observed deficiency in students' process skills suggests a possible cause for their performance challenges, likely stemming from the absence of novel instructional approaches. This observation is in line with the Chief Examiner's reports of West African Examinations Council in 2019 and 2020, and the study conducted by Amoah et al. in 2021. These sources substantiate the assertion that a lack of or insufficient development of process skills contributes to students' difficulties in Integrated Science practical tests. The gap in students' process skills presents a significant issue in their science education, hindering their ability to effectively apply scientific principles in practical contexts, and hence must be addressed to ensure that students receive a comprehensive science education. Given the significance of this gap, it is critical to utilise innovative teaching methods (Mehta, 2019) that engage students actively (Callanhan & Dopico, 2016) and provide them with opportunities to nurture and refine these essential skills (Mehta, 2016). It has become increasingly evident that the traditional approach to science education, which emphasises the mere delivery of content knowledge, is no longer adequate to produce the well-rounded, scientifically literate individuals that society now demands (Holbrook & Rannikmae, 2007; Inayah et al., 2020).

Consequently, to address this educational imperative, educators and researchers have been exploring novel pedagogical strategies that promote both content mastery and process skill development. As such, shown by Mehta (2016), one such promising approach involves the integration of advance organisers within a cooperative learning framework. Advance organisers are teaching techniques employed by educators to introduce lesson topics and demonstrate to students how the new material relates to what they have already learnt. By presenting relevant information before class, students are equipped with the necessary background knowledge to aid in understanding, recalling, and retaining newly learned material (Somashekhara & Dange, 2020). They are tools that help students make meaningful connections between prior knowledge and new information (Oyeniyi & Owolabi, 2020; Patel, 2016). Ausubel's theory of meaning learning (Ausubel, 2000) underpins the use of advanced organisers. By activating prior knowledge and providing a conceptual scaffold (Hoffman et al., 2021), advance organisers assist students to understand, retain, and remember the new learning material (Somashekhara & Dange, 2020). Nyabwa (2005) highlighted that the use of advance organisers provides suitable learning opportunities to students, and motivating them to acquire various skills and knowledge. KWL chart, graphic, skimming, and expository organisers are the most prevalent forms of advance organisers. KWL chart enables students to review their past knowledge (What I Know), articulate their learning goals (What I Want to Know), and consider what they have learned (What I Learnt). With the use of graphic organisers, students and teachers are able to recognise and connect important ideas and concepts in a visual way. Additionally, skimming allows students to quickly glance over and outline the material they require to study whiles the expository advance organiser shows the new information that will be taught as the teacher presents students with important concepts and ideas (Apeadido & Amedeker, 2023).

Cooperative learning is an instructional approach where two or more students work together with a shared goal, aiming to achieve specific learning outcomes through their collective efforts. This method emphasises joint participation, mutual support, and shared responsibility among students, leading to improved achievement and results in classroom teaching (Bada & Jita, 2022; Nanor et al., 2024). Cooperative learning strategies, guided by Johnson and Johnson's cooperative learning theory and implemented through appropriate approaches (Johnson & Johnson, 2016; Johnson, Johnson, & Holubec, 2008), encourage peer collaboration and motivate students to participate more actively in the teaching and learning process (Mendo-Lazaro et al., 2022). These strategies offer students the chance to learn by applying knowledge in an environment more similar to the one they will encounter in their future work lives (Rigacci, 2008), which creates a conducive environment for enhancing essential skills (Sunasuan & Songserm, 2021; Mendo-Lazaro et al., 2022). Cooperative learning, when coupled with advance organisers, cultivates an environment where students actively collaborate, engage in constructive discussions, and apply scientific principles collectively (Mendo-Lazaro et al., 2022; Sunasuan & Songserm, 2021; Mehta, 2016; Oyeniyi & Owolabi, 2020). The combined use of advance organisers within cooperative learning environments offers a powerful pedagogical approach. The study by Mehta (2016) examined the integration of concept mapping as an advance organiser in a cooperative learning setting. It found that this combined approach enhanced student engagement by providing a structured framework for collaborative problem-solving, thereby enhancing their process skills.

Despite the potential benefits of this innovative approach, there remains a substantial gap in our understanding of how precisely advance organisers and cooperative learning influence the development of process skills in the context of Integrated Science (Sunasuan & Songserm, 2021; Mehta, 2016). This gap limits educators' ability to implement evidence-based teaching practices that effectively address the root causes of poor student performance. This study aimed to bridge this critical gap by investigating the impact of advance organisers on the acquisition and development of students' science process skills within a cooperative learning classroom in Integrated Science. The study sought to determine the science process skills that students would acquire and demonstrate when taught Integrated Science using advance organisers in a cooperative learning classroom. In addition, it sought to determine the effect of advance organisers on the development of students' science process skills in Integrated Science in a cooperative learning classroom. Moreover, the study sought to test two null hypotheses at a significance level of 0.05 associated with the stated objectives.

Research Questions

1. What science process skills do students acquire and demonstrate when taught Integrated Science using advance organisers in a cooperative learning classroom?
2. How does the use of advance organisers within a cooperative learning classroom impact the development of science process skills in students engaged in Integrated Science learning?

Research Hypotheses

1. Null Hypothesis One ($H0_1$): There is no significant difference in the acquisition and demonstration of science process skills by students when taught Integrated Science using advance organisers in a cooperative learning classroom.
2. Null Hypothesis Two ($H0_2$): There is no significant difference in the development of science process skills among students engaged in Integrated Science learning with the use of advance organisers in a cooperative learning classroom.

Significance of the study

The significance of the study lies in its exploration of the acquisition, demonstration, and development of science process skills among students when taught Integrated Science using advance organisers in a cooperative learning classroom. By focusing on this specific aspect, the research fills a critical gap in literature, offering important insights into efficient teaching techniques for improving science education. The findings have practical implications for educators, curriculum developers, and policymakers, informing the design and implementation of instructional approaches that promote essential process skills development. Ultimately, the study contributes to advancing pedagogical practices in science education and emphasises the importance of incorporating innovative teaching strategies to foster students' scientific inquiry and critical thinking abilities.

Methodology

Research Design

The study employed a one-group pre-test and post-test design mixed with qualitative research methods, specifically observation. The one-group pre-test and post-test design is a quasi-experimental design used to evaluate the effectiveness of a treatment or intervention within a single group of participants, where data is collected from the same group of participants before (pre-test) and after (post-test) they receive the intervention (Choueiry, 2021). Complementing the quantitative assessments, qualitative methods, such as classroom observations, were utilised throughout the intervention. Observations involve systematically noting and recording participants' behaviours and interactions in real-time within the context of the intervention, facilitating a deeper understanding of how participants engage with the intervention and their reactions to it (Hopkins, 2017). This mixed-methods research design allowed the researchers to assess the effectiveness of the intervention on a class of students through both quantitative measures (pre-test and post-test scores) and qualitative observations, providing a more holistic understanding of the research questions.

Population and Sampling

Based in Ghana's Ashanti Region of Ghana, the study was conducted at Adugyama Senior High School. This particular school was chosen with special consideration because one of the researchers had previously worked for this institution and is therefore well-versed in the learning environment there. The target population was all form-three students. The Form 3 classes were chosen because this particular set of students struggles to correctly respond to the practical questions requiring science process skills on the WASSCE Integrated Science test. The purposive sampling technique was used to select a sample of 44 form-three General Art students in the class**,** 3A4, for the study. Purposive sampling involves choosing participants based on pre-determined criteria relevant to the study's aim and objectives (Nikolopoulou, 2023). This sampling technique was used to select these students who are regular attendees to Integrated Science lessons and are suitable for the research design for this study.

Research Instruments

The instruments used to collect data from the research subjects were the pre-test and post-test, observation checklist, weekly intervention exercises, and scoring rubric.

1. The pre- and post-tests were administered to assess the students' level of science process skills before and after the intervention. The tests included practical-based questions or tasks related to various science process skills such as observation, measurement, drawing, inference, recording, experimentation, and data interpretation, from the content area, measurement and plotting of linear graph in Integrated Science. The tests had 10 items made up of open-ended questions and were scored out of 50. The scores from the pre-test and post-test were recorded using a scoring rubric to measure any improvement or changes in the students' skills over time.
2. The observation checklist was used to systematically observe and record the students' behaviour and engagement during the intervention lessons. It had 30 items related to 10 different science process skills (observation, measurement and recording, drawing and recording, prediction, inference, communication, hypothesis formulation, experimentation, manipulation, and data interpretation) intended to be observed through demonstration and enhancement. Each of the 10 science process skills has three sub-items, making a total of 30 items across the checklist. The checklist helped the researchers monitor the students' progress and identify any areas for improvement or challenges.
3. The weekly intervention exercises were designed to reinforce the learning objectives of the intervention lessons and allow students to practice and apply their science process skills. The exercises included hands-on activities, group tasks, and practical tests covering various aspects of measurement in Integrated Science. Each exercise had four open-ended item questions, scored out of 20. They provided opportunities for students to demonstrate their skills in observation, measurement, recording, drawing and labelling, data interpretation, communication.

4. The scoring rubric, ultimately, was used to assess and evaluate the students' performance on the pre-test, post-test, checklist, and intervention exercises. It provided clear criteria and benchmarks for scoring each task or activity, ensuring consistency and objectivity in the assessment process. The rubric included specific indicators or descriptors for each science process skill being assessed, allowing for a comprehensive evaluation of the students' abilities.

By systematically employing these instruments throughout the research process, the researchers were able to monitor students' development, quantify learning outcomes, and assess the impact of the intervention on skill acquisition, demonstration, and enhancement within the context of cooperative learning.

Validity and Reliability of the Instruments

The validity of the instruments was determined by subjecting them to experts, including a senior lecturer at the University of Education, Winneba, and two senior high school Integrated Science teachers who had more than five years of teaching experience, for their suggestions and corrections. The instruments were field pilot-tested on 20 form-three General Art students at Mankranso Senior High School located at the Ahafo Ano South West District of the Ashanti Region with characteristics comparable to the school where the research was carried out in order to determine the reliability. The instruments were utilised to gather data from the chosen students, and the analysis showed that each item had a strong correlation with the total score test, with an Alpha Cronbach value of 0.83.

Intervention Strategy

The intervention strategy, implemented by one of researchers, comprised five lessons designed to teach selected practical Integrated Science concepts using advance organisers, innovative cooperative instructional techniques, and related teaching and learning resources such as practical tools, diagrams and charts. Each lesson, which lasted for 90 minutes per day in a week, was tailored to foster science process skills acquisition, demonstration, and development by focusing on a specific topic: measurement of length (in lesson one), volume (in lesson two), time, mass and weight (in lesson three), density (in lesson four), and plotting of linear graphs with determination of slope (in lesson five).

In the lesson on measurement of length, students were guided to identify, describe, and accurately use length measuring instruments like the metre rule, Vernier calliper, and Micrometer screw gauge, promoting skills such as observation, drawing, measurement, and data recording and interpretation. Similarly, the lesson on measurement of volume aimed to enhance skills in observation, measurement, manipulation, experimentation, and communication as students identified volume measuring instruments, used them accurately, and performed simple volume calculations using resources like the measuring cylinder, volumetric flask, and metre rule. In the subsequent lesson focusing on measurement of time, mass, and weight, students honed their skills in observation, drawing, measurement, data recording, and communication by accurately reading time measuring instruments and using mass and weight measuring tools. The lesson on measurement of density deepened students' understanding of scientific concepts and fostered skills in observation, drawing, hypothesis formulation, manipulation, experimentation, and communication as they explored the concept of density and conducted experiments to determine the density of substances. Finally, the lesson on plotting linear graphs and determining slope promoted skills in measurement, data recording, analysis, inference, and data interpretation as students correctly recorded data, plotted graphs, and interpreted results. Throughout the intervention, students engaged with hands-on activities and interactive tasks, facilitated by the researcher, fostering active participation, deep understanding of the concepts, and proficiency in essential science process skills. Additionally, weekly exercises conducted throughout the intervention, aligned with each lesson's objectives, provided opportunities for students to apply and reinforce their newly acquired skills, with feedback incorporated to support continuous improvement.

The intervention strategy was implemented in four stages in all the five lessons, ensuring a structured approach to learning and assessment. The stages are explained below:

Stage one: Introduction and use of advance organisers: The introduction of lesson involving advance organisers began with a review of students' relevant previous knowledge. This step was vital to reminding students of their prior knowledge and making connections between it and new information that will help them learn more in the future. Students were provided with a broad overview of the lesson's objectives before its commencement, ensuring clarity and focus. Additionally, graphic organisers such as concept maps and visual representations of key terms and concepts were presented to students prior to the lesson, facilitating comprehension and organisation of information. Moreover, students were guided in utilising KWL ("What I Know", "What I Want to Know", "What I Learned") charts, an organised strategy that encouraged active participation and metacognitive reflection (Storm, 2023). In this regard, the students were aided to divide a page into three columns, then use one column to write what they think they know and use second column for what they want to know prior to a lesson, and use the third column for what they've learnt after the lesson. This multifaceted approach to advance organisers intervention lessons aimed to scaffold students' learning experiences, promote deeper understanding, and foster meaningful connections between prior knowledge and new content (Somashekhara & Dange, 2020; Hoffman et al., 2021; Patel, 2016).

Stage two: Use of cooperative learning strategies: The main lesson was conducted within a cooperative learning environment, following the introduction of advance organisers to prepare students for the learning tasks ahead. Throughout the five lessons, various cooperative learning activities were employed to facilitate collaborative engagement and knowledge construction among students. These activities included Think-pair-share, Jigsaw method, numbered-heads together, cooperative problem solving, and cooperative group tasks. To create the cooperative learning environments based on these strategies, specific steps were followed tailored to each approach. For the Think-Pair-Share method, students were presented with a topic or question to consider individually, then paired up with a classmate to discuss their thoughts, and finally, shared their ideas or responses with the entire class (Rigacci, 2020). In implementing the Jigsaw method, the topics or tasks was divided into sections, with each section assigned to a small group of students who became experts on their assigned section and then regrouped to share their expertise (Colorin Colorado, 2018). For the Numbered-Heads Together strategy, students were organised into small groups and assigned a number as their group identity. In order to reach a consensus on a topic presented by means of questions, the students were allowed to work in small groups. The students, whose names are stated, were required to respond to the teacher's questions (Alfayed, 2018). In cooperative problem solving, students were presented with complex problems or challenges requiring collaborative effort within small groups, where they analysed the problems collectively, brainstormed potential solutions, and collaborated on developing problem-solving strategies. Lastly, cooperative group tasks involved assigning assignments, tasks, or exercises for groups to work on collectively, leveraging the diverse skills and knowledge of each member to complete the tasks. Through these structured approaches, cooperative learning environments that promoted active student participation, peer interaction and exchange of ideas, were effectively created, fostering a supportive and engaging atmosphere for learning and achievement.

During the cooperative learning sessions, individual and group performances were closely monitored as students engaged in practical tasks. Any requests for clarification from individuals or groups were addressed promptly to ensure a clear understanding of the tasks. Additionally, questions were posed to stimulate critical thinking and encourage effective collaboration among students within their respective groups. This proactive approach aimed to facilitate the demonstration and development of science process skills within the cooperative learning environment, fostering a supportive and engaging atmosphere for student learning and participation.

Stage three: Assessment: Throughout the intervention period, weekly exercises were administered at the conclusion of each of the five lessons, and students' performances were carefully assessed. Individual and group performances were evaluated using worksheets and observation checklists, with specific criteria tracked to monitor progress. The students' adaptation to instructional strategies and advance organisers was assessed based on their demonstration and development of science process skills. Furthermore, the students' science process skills exhibited during the lessons were assessed to gauge their comprehension and application of the concepts taught. The formative assessments conducted through various practical tests, were presented in weekly exercise books for completion. Assessments were distributed to students in groups of four, groups of two, or individually, depending on the nature of the assessment and the concept being evaluated. Collaboration among students during evaluation exercises was prohibited to ensure the integrity of the assessments. Following marking and scoring, the weekly exercises were collected and analysed to identify trends and assess student progress effectively.

Stage four: Feedback: In addition to assessing student performance, feedback was provided to guide students' progress throughout the lessons. After each session, general discussions were held to address practical activities and provide constructive feedback. Students were categorised as above average, average, or below average based on their individual participation and group work. Weaknesses related to the use of advance organisers, misrepresentation of scientific process skills, misconceptions of topics, and comprehension issues were identified and remedied. Students or groups showing improvement were praised or rewarded, fostering a culture of recognition and encouragement for both individual and collective achievements. This approach aimed to motivate students to engage actively in learning and collaborate effectively in group settings.

Data collection Procedure

Three phases of data collection were conducted: pre-intervention, intervention, and post-intervention. In the pre-intervention phase, students' skills were assessed through interaction and analysis of their assessment records to identify both demonstrated and lacking skills. Additionally, a pre-test was administered to gauge students' level of process skill development, with results recorded using a scoring rubric. During the five-week intervention phase, students were taught measurement concepts and graph plotting in Integrated Science using advance organisers and cooperative learning techniques. Science process skills demonstrated during intervention lessons were recorded through weekly exercises and observational checklists. At the end of each lesson, students undertook assessment in groups and individually through group tasks and practical tests, which were subsequently marked and recorded. At the post-intervention phase, a post-test was administered to evaluate the impact of the intervention strategy on science process skill development, with results recorded using the scoring rubric. The rubric was used to compare the pre- and post-assessment results comprehensively, aiding in determining the impact of intervention on the students' science process skills development.

Data Analysis Techniques

The data analysis involved summarising and interpreting the qualitative and quantitative data collected from the instruments needed to address the research questions. The qualitative and quantitative data collected through observation checklists and pre-test, weekly intervention exercises, and post-test scores, respectively, were analysed using descriptive statistics, including frequencies, percentages, means and standard deviations. Additionally, the paired samples t-test was used to assess whether there is a significant difference between the pre-test and post-test scores, providing statistical evidence of the intervention's effectiveness.

The pre- and post-intervention phases of the study were used to determine students' science process skills demonstration and development according to the criteria for data interpretation listed in Table 1 (Appendix A). The mean scores for each science process skill were obtained by averaging the number of students who successfully acquired, demonstrated, and developed each specific skill, based on the criteria outlined.

Results

The outcomes of the assessments are presented in the upcoming tables, providing insights into how the intervention programme positively impacted students' science process skills.

Impact of intervention on the science process skills acquisition and demonstration

In this part, the results of the impact of the intervention involving the use of advance organisers in a cooperative learning classroom on the acquisition and demonstration of science process skills among students are presented. The findings are organised to include an examination of the descriptive statistics of science process skills exhibited by students across five lessons, as well as a paired t-test analysis of pre- and post-test scores on skill acquisition and demonstration. Tables 2 to 4 provide a detailed overview of the results, which are accompanied by their interpretations.

Table 2 Science process skills students were observed to have demonstrated in five lessons

		Lesson (L)					Number of lessons that process skills were observed
N	**Science process skills**	L1	L2	L3	L4	L5	
1	Observation	⦿	⦿	⦿	⦿	⦿	5
2	Measuring and Recording	⦿	⦿	⦿	⦿	⦿	5
3	Drawing and Labelling	⦿	⦿	⦿	⦿	⦿	5
4	Prediction	○	⦿	⦿	⦿	⦿	4
5	Communication	⦿	⦿	⦿	⦿	⦿	5
6	Inference	○	⦿	○	⦿	⦿	3
7	Formulation of hypothesis	○	⦿	○	⦿	⦿	3
8	Experimentation	⦿	⦿	⦿	⦿	⦿	5
9	Manipulation: Controlling variables	⦿	⦿	⦿	⦿	⦿	5
10	Interpreting data	○	⦿	⦿	⦿	⦿	4

[1]⦿ represents Observed; [2]○ represents Not observed;

The data presented in Table 2 show whether or not students were observed demonstrating the various science process skills in five lessons.

The results in Tables 2 show that the students consistently demonstrated observation, measuring/recording, and drawing/labelling skills in all five lessons. This indicates they do employ these foundational skills, which are essential for scientific inquiry and experimentation. Prediction, communication, and interpreting data skills were also exhibited by students but not in all the lessons. While prediction and interpreting data were observed in four of the lessons, inference and formulation of hypothesis were observed in only three lessons.

Communication skills were demonstrated across the five lessons, suggesting that the students were adept at making predictions based on their observations and effectively communicating their findings. Inference and formulation of hypothesis skills were also evident, although not observed in all lessons compared to other skills. This indicates a reasonable level of proficiency in drawing conclusions based on evidence and formulating hypotheses to guide further investigation.

However, it is notable that basic skills such as observation, measuring/recording, and drawing/labelling were exhibited in all lessons compared to integrated process skills like inference, formulation of hypotheses, and interpretation of data. This indicates a stronger emphasis on foundational aspects of scientific inquiry, providing students with a solid grounding in fundamental concepts and practices. The low emphasis on integrated process skills suggests a potential gap in the curriculum where opportunities for students to develop higher-order thinking abilities could be enhanced. Nonetheless, the data suggests that students have acquired a diverse range of science process skills at a consistent level at across the five lessons when taught Integrated Science using advance organisers in a cooperative learning classroom.

The mean scores for each science process skill were obtained by averaging the number of students who successfully acquired, demonstrated, and developed each specific skill, based on the criteria outlined.

(SD difference = 11) shows more consistent student performance in skills acquisition and demonstration after the intervention. However, skills such as inference and hypothesis formulation, show increased

Table 3 **Descriptive statistics of percent scores obtained for science process skills acquired and demonstrated**

	Pre-Intervention		Post-Intervention			
Science process skills	Mean	SD	Mean	SD	Mean Diff.	SD
Observation	63	48	93	25	30	23
Measuring and Recording	56	50	90	29	34	21
Drawing and Labelling	43	50	81	39	38	11
Prediction	29	46	72	45	43	1
Communication	43	50	84	36	41	14
Inference	22	42	59	49	37	7
Formulation of hypothesis	22	42	65	47	43	5
Experimentation	31	47	79	40	48	7
Manipulation	34	47	77	42	43	5
Interpreting data	29	46	72	45	43	1

The descriptive statistics in Table 3 highlight students' acquisition and demonstration of science process skills before and after the intervention. The pre-intervention means and standard deviations reveal baseline levels of skill performance, with observation skills being highest at a mean of 63 (SD = 48), and inference skills the lowest at 22 (SD = 42). Post-intervention data show notable improvements: observation skills increased to a mean of 93 (SD = 25) and inference skills rose to 59 (SD = 49). The mean differences indicate significant gains, such as a 43 increase in data interpretation and prediction skills, with a minimal change in variability (SD difference of 1), suggesting consistent improvement post-intervention. Additionally, the reduced variability in communication (SD difference = 14) and drawing and labelling variability, indicating that progress was not uniform across all skills. For example, while the mean difference for inference was 37, the standard deviation difference of 7, shows some inconsistencies in skill demonstration, suggesting the need for further targeted interventions to ensure more uniform skill acquisition and demonstration among all students. Overall, the data suggest that the intervention resulted in satisfactory improvements in the students' acquisition and demonstration of science process skills.

Though the data suggest the intervention resulted in satisfactory improvements in the students' acquisition and demonstration of science process skills, it was further analysed to ascertain whether or not the change observed in the pre-intervention and post-intervention results were statistically significant. A paired samples t-test was carried out on the results to test the null hypothesis that "there is no significant difference in the pre- and post- intervention mean scores in science process skills of students taught Integrated Science using advance organisers in a cooperative learning classroom". The results of the paired samples t-test are presented in Table 4.

Table 4 **Paired samples t-test results of differences between the students' percent scores in skill acquisition and demonstration of science process skills in pre- and post- test**

Science process skills	Pre-Mean	Post-Mean	Mean Diff.	t Stat	t Critical	p (2-tailed)	Interpretation
Observation	63	93	30	4.24	2.01	< 0.001*	Reject HO_1
Measuring and Recording	56	90	34	4.71	2.01	< 0.001*	Reject HO_1
Drawing and Labelling	43	81	38	5.20	2.01	< 0.001*	Reject HO_1
Prediction	29	72	43	5.71	2.01	< 0.001*	Reject HO_1
Communication	43	84	41	5.45	2.01	< 0.001*	Reject HO_1
Inference	22	59	37	4.95	2.01	< 0.001*	Reject HO_1
Formulation of hypothesis	22	65	43	5.71	2.01	< 0.001*	Reject HO_1
Experimentation	31	79	48	6.26	2.01	< 0.001*	Reject HO_1
Manipulation	34	77	43	5.71	2.01	< 0.001*	Reject HO_1
Interpreting data	29	72	43	5.71	2.01	< 0.001*	Reject HO_1

*Note. Number of participants = 44, t Critical = 2.01, *p < 0.05*

Based on the provided data in Table 4 and the hypothesis that there is no significant difference in the acquisition and demonstration of science process skills by students when taught Integrated Science using advance organisers in a cooperative learning classroom, the results indicate otherwise. The mean difference between pre- and post-test scores for each science process skill is statistically significant, as evidenced by the t-test statistics (t Stat) being substantially larger than the critical t-value (t Critical) at a significance level of $p < 0.05$ for all skills. Additionally, the p-values (p) are all less than 0.05, indicating strong evidence of rejecting the null hypothesis as evident in Table 4. For example, considering the observation skill, the mean difference between pre- and post-test scores was 30, with a t-test statistic of 4.24 ($p < 0.05$), indicating a significant improvement. This suggests that the intervention effectively enhanced students' ability to make observations in scientific contexts. These findings are consistent across all science process skills measured, with mean differences ranging from 30 to 48 and t-test statistics exceeding the critical value at $p < 0.05$ for each skill. This suggests that the intervention of teaching Integrated Science using advance organisers in a cooperative learning classroom has indeed led to a significant positive difference in students' acquisition and demonstration of science process skills (students' learning outcomes) across all measured areas. Therefore, the results provide compelling evidence disapproving the null hypothesis, indicating a positive and meaningful effect of the intervention on students' skill acquisition and demonstration.

Impact of intervention on the development of science process skills

In this sub-section, the results of the impact of the intervention, involving the use of advance organisers in a cooperative learning classroom, on the development of science process skills among students are presented. Tables 5 to 8 provide a comprehensive overview of the comparisons between the pre-assessment and post-assessment phases.

In the initial assessment, as shown in Table 5, a substantial number of students found themselves in the Unsatisfactory category across all the skills. This demonstrated the existing challenges in these fundamental areas of science process skills. Proficiency levels were notably low, with only a small number of students demonstrating Proficient levels.

The assessment results, as indicated in Table 6, reveal the impact of the intervention lessons on students' science process skills development when compared to Table 5. The comparison reveals a notable improvement in students' science process skills from pre-assessment to post-assessment. In the domain of Observation and Measuring Skill Proficiency, a significant improvement is evident, with 35 students demonstrating proficient level (good skill) level, compared to only 7 initially (as shown in Table 5). Similarly, Drawing and Labelling, and Communication Skills Proficiency witnessed a notable shift, with the majority of students now showing Basic and Proficient levels. Also, Hypothesis formulation and Inference,

Table 5 **Pre-assessment of levels of proficiency (i.e., unsatisfactory, basic and proficient) of students' process skills**

	Students reaching level of proficiency			
Science process skills	Unsatisfactory	Basic	Proficient	Total
Observation, Measuring and Recording	13	24	7	44
Drawing and Labelling	25	17	2	44
Hypothesis formulation and Inference	34	7	3	44
Communication	25	14	5	44
Experimentation and Manipulation	29	9	6	44
Data Interpretation	31	11	2	44

Table 6 **Post-assessment of levels of proficiency (i.e., unsatisfactory, basic and proficient) of students' process skills**

	Students reaching level of proficiency			
Science process skills	Unsatisfactory	Basic	Proficient	Total
Observation, Measuring and Recording	3	6	35	44
Drawing and Labelling	8	15	21	44
Hypothesis formulation and Inference	15	18	11	44
Communication	7	13	24	44
Experimentation and Manipulation	9	17	18	44
Data Interpretation	12	18	14	44

and Data interpretation Skills Proficiency showed considerable progress, as 29 and 32 students exhibited certain levels of skills, respectively. Evidently, the findings suggest that the intervention has possibly led to substantial enhancements in students' science process skills, resulting in a higher proportion of students achieving proficient levels post-assessment.

The comparison of means and standard deviation in Table 7 further reinforces the positive impact of the intervention on the development of the students' science process skills. The data show significant improvements in mean proficiency levels across all skill categories, from pre-assessment to post-assessment. Notably, the mean proficiency level for unsatisfactory skills has decreased significantly (from 26.16 to 9.00) after the intervention, while the mean proficiency level for proficient skills has increased considerably (from 4.16 to 20.50).

These results indicate a shift towards higher levels of skill proficiency among students after the implementation of the intervention. Additionally, the substantial decreases in standard deviations across all skill categories, particularly for unsatisfactory and basic skills, indicate a more consistent improvement in students' performance levels following the intervention. This reduction in variability suggests that the intervention has effectively narrowed the gap in skill proficiency among students, leading to more uniform and reliable outcomes. Overall, the comparison of means and standard deviations highlights the effectiveness of the intervention in enhancing students' science process skills and facilitating their progression towards higher levels of proficiency.

Table 7 **Comparison of skill proficiency levels between pre- and post-assessment results**

	Pre-Assessment		Post-Assessment	
Skill Proficiency Level	Mean	Std. Dev.	Mean	Std. Dev.
Unsatisfactory	26.16	7.33	9.00	4.14
Basic	13.66	6.18	14.50	4.59
Proficient	4.16	2.13	20.50	8.50

Furthermore, Table 8 shows the results of a paired t-test analysis of pre- and post-test scores to test the null hypothesis that “there is no significant difference in the development of science process skills among students engaged in Integrated Science learning with the use of advance organisers in a cooperative learning classroom”.

Table 8 Paired samples t-test analysis of pre- and post- test scores of skill development

Science process skills	Pre-Assessment Proficient level (n = 44)		Post-Assessment Proficient level (n = 44)		t-test stats	p-value	Interpretation
	Mean	SD	Mean	SD			
a) Observation, Measuring and Recording	15	36	79	40	8.67	< 0.001*	Reject HO_2
b) Drawing and Labelling	4	20	47	50	5.71	< 0.001*	Reject HO_2
c) Hypothesis Formulation and Inference	6	24	25	43	3.09	< 0.05*	Reject HO_2
d) Communication	11	32	54	50	5.71	< 0.001*	Reject HO_2
e) Experimentation and Manipulation	13	34	40	49	4.01	< 0.001*	Reject HO_2
f) Interpreting data	4	20	31	47	4.01	< 0.001*	Reject HO_2

*Note. Number of participants = 44, t Critical = 2.01, *p < 0.05*

Based on the provided results in Table 8, it's evident that there is a significant difference in the development of science process skills among students engaged in Integrated Science learning with the use of advance organisers in a cooperative learning classroom. The t-test statistics (t Stat) for various evaluated science process skills revealed a substantial difference between the pre- and post-assessment means, with values exceeding the critical t-value (t Critical) at a significance level of $p < 0.05$ for all skills. Additionally, all p-values (p) are less than 0.05, providing strong evidence to reject the null hypothesis. For instance, for the mean score of observation, measuring, and recording increased significantly from 15 in the pre-assessment to 79 in the post-assessment ($t = 8.67$, $p < 0.05$), indicating substantial improvement. Similarly, for Drawing and Labelling, there was a significant increase from a mean score of 4 to 47 ($t = 5.71$, $p < 0.05$), suggesting notable enhancement in this skill. This improvement is consistent across other skills, such as hypothesis formulation and inference, communication, experimentation and manipulation, and interpreting data, where similar trends are observed with statistically significant mean differences and t-test statistics. This implies that the intervention has led to a significant improvement in students' development of science process skills across all evaluated areas. Therefore, the findings robustly disproved the null hypothesis and supported the alternate hypothesis, indicating that the use of advance organisers in a cooperative learning setting has positively impacted students' skill development.

Discussion

The findings show that the students acquired and demonstrated diverse science process skills: Observation, measuring and recording, drawing and labelling, communication, experimentation, manipulation skills, prediction, inference, data interpretation skills, and hypothesis formulation. Additionally, the findings reveal a balanced frequency of use of the process skills, leading to a well-rounded acquisition of scientific inquiry abilities among the students. This underscores the effectiveness of the instructional approach (use of advance organisers in a cooperative learning setting) to fostering a holistic understanding of science and promoting active engagement in the learning process and subsequently facilitating the demonstration of the scientific skills of the learners. These findings are coherent with outcomes of Prayitno et al. (2017), Tsobaza and Njoku (2021), and Saat (2004). The outcomes of these study revealed that instructional approaches that focus on student-centred setting facilitates the acquisition and demonstration of science process among students. Moreover, the demonstration of basic science process skills much more than integrated science process skills agree with the outcome of Akinbobola and Afolabi (2010), who revealed that because students are not used to being taught integrated science process skills, they are more difficult to improve or demonstrate. A similar finding was made in a study by Padilla (2018), who indicated that teachers cannot expect mastery of experimenting or integrated skills from students after a few practice sessions; instead, students should be given multiple opportunities to work with these skills in different content areas and contexts. This data interpretation implies that while students have a strong grasp of basic scientific principles, there may be room for improvement in integrating more complex analytical and reasoning skills into their scientific investigations. Strengthening the integration of these higher-level skills could enrich students' understanding of scientific concepts and enhance their ability to critically evaluate data and draw meaningful conclusions. It emphasises the importance of incorporating a balanced approach to science education focusing on both foundational skills and higher-order thinking abilities to foster comprehensive scientific literacy among students.

The findings, furthermore, indicate a noticeable enhancement in students' science skills, which underscores the effectiveness of the instructional approach on skill development in science education. Padilla (2018) was of the opinion that students learn science process skills better if they are considered an important object of instruction and if proven teaching methods are used. Additionally, Colley (2006) asserted that science process skills require instructional approaches that place emphasis on active learning, student-directed learning, and integration of content and process. Therefore, it can be deduced that the teaching of practical lessons through the use of advance organisers in a cooperative learning environment created more opportunities for the students to develop their science process skills. These findings are consistent with the findings of Sulistri (2019), who stated that when students are taken through a learning model that pays attention to and considers students' initial knowledge, provides a series of experiences in the form of real activities, and allows social interactions among them, their science process skills are improved. Ekon and Eni (2015) and Mandor (2002) research findings were also in agreement with the findings of this study by demonstrating that active involvement of students during classroom activities enables students to apply their five senses to their lessons, which contributes to the acquisition and development of more science process skills in students. Moreover, the findings of this study are similar to those of Mehta (2016), who revealed that the use of advance organisers with cooperative learning strategies plays a vital role in developing process skills in students.

Conclusion

This study showed that using advance organisers within a cooperative learning setting positively impacts students' acquisition and development of science process skills within the context of Integrated Science education. Though basic process skills were demonstrated more frequently compared to integrated process skills, which were demonstrated less often, the overall findings highlight the enhanced acquisition and demonstration of various science process skills as well as the development of these skills among the learners. These findings underscore the effectiveness of the instructional strategy in fostering science process skills while also emphasising the need for further exploration and promotion of integrated process skills within the Integrated Science curriculum. The implications of this study highlight the importance of incorporating this instructional strategy to enhance students' holistic understanding and application of science process skills.

Recommendations

Based on the findings of this study, the following recommendations are given:

1. Educators can leverage advance organisers with cooperative learning strategies as a powerful tool to facilitate students' science process skill acquisition and enhancement.
2. Educators should strive to strike a balance between teaching and emphasising both basic and integrated process skills, since both are equally important for holistic scientific understanding. Educators are urged to design lessons that explicitly incorporate opportunities for students to demonstrate these skills.
3. Curriculum developers and educational policymakers should consider aligning curriculum guidelines with the promotion of integrated science skills.
4. Future research can delve deeper into the nuances of advance organisers and cooperative learning strategies. Research may explore the specific design elements of advance organisers that yield optimal results and how they vary across contexts. Also, extending this research to diverse educational settings and subject areas can broaden our understanding of the generalisability of these findings.
5. Researchers are encouraged to conduct longitudinal studies that track the long-term impact of advance organisers on science process skill development.

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Appendix A **Table 1: Science process skills assessment rubric**

N	Science process skills (General Interpretation)	Criteria		
		Unsatisfactory *(Lack of skill)*	**Basic *(Some skill)***	**Proficient *(Good sk***
1	*Observation* (Foundational skill for data collection)	• Makes vague or inaccurate observations • Struggles to identify key features of instruments. • Fails to identify trends in events	• Makes some observations but lacks detail or precision. • Struggles to identify all components of instruments. • May struggles to identify patterns	• Makes detailed and acc observations. • Identifies all componen instruments with precis • Notices patterns in ever
2	*Measuring and Recording* (Essential skill for precise data collection)	• Struggles to read measurements accurately. • Makes frequent errors in using units. • Unable to record data effectively.	• Reads measurements with some accuracy. • Makes occasional errors in using units. • Records data inconsistently.	• Reads measurements ac • Consistently uses appro units. • Records data systemati accurately
3	*Drawing and Labelling* (Important for documenting observations)	• Struggles to draw accurately • Label diagrams inaccurately. • Lacks detail in representations.	• Draws diagrams with some accuracy. • Labels some components. • Struggles to represents details effectively (may omit details)	• Draws accurate diagram • Labels all components precisely • Represents details effec
4	*Prediction* (Important for hypothesis generation)	• Struggles to make predictions based on measurements. • Lacks understanding of concepts. • Fails to apply concepts effectively.	• Makes predictions with limited accuracy. • Demonstrates partial understanding of concepts. • Struggles to apply concepts effectively.	• Makes accurate predict on measurements. • Demonstrates clear und of concepts. • Applies concepts effect
5	*Communication* (Crucial for conveying findings effectively)	• Struggles to articulate measurement concepts or express them clearly • Responses lack coherence and organisation and organisation	• Communicates measurement concepts with clarity but may lack precision • Responses are somewhat organised but lack detail	• Communicates ideas cl effectively. • Responses are well-org coherent and detailed.

N	Science process skills (General Interpretation)	Criteria Unsatisfactory *(Lack of skill)*	Basic *(Some skill)*	Proficient *(Good sk*
		• Struggles to convey information to peers or instructors.	• Able to convey information to peers or instructor with moderate clarity	• Conveys information to instructors with clarity, understanding of measu topics.
6	Inference (Essential for drawing logical conclusions)	• Struggles to make inferences. • Lacks logical conclusion • Unable to apply concepts to new situations (lacks logical reasoning)	• Makes some inferences. • May struggle with logical conclusion • Struggles to apply concepts to new situations (struggles with logical reasoning)	• Makes accurate inferen on measurements. • Demonstrates strong lo conclusion. • Applies concepts to nev (shows logical reasonin
7	Formulation of hypothesis (Critical for guiding investigations)	• Struggles to formulate hypotheses related to measurements or observations. • Fails to provide an explanation for hypothesis • Fails to demonstrate understanding of variables of measurement concepts	• Formulates hypotheses with limited relevance or specificity. • May struggle to provide an explanation for the hypothesis • Struggles to demonstrate understanding of variables of measurement concepts.	• Formulates clear and re hypotheses related to measurements or obser • Provides an explanatior hypothesis. • Demonstrate understanc variables of measureme concepts.
8	Experimentation (Key for hands-on learning and understanding scientific methods)	• Struggles to conduct experiments effectively. • Demonstrates confusion about procedures. • Makes frequent errors in following experimental protocols.	• Conducts experiments with limited effectiveness. • May encounter difficulties in following complex procedures. • Requires occasional guidance or clarification on experimental protocols.	• Conducts experiments c and accurately. • Follows established prc with precision. • Demonstrates a clear understanding of experi procedures.
9	Manipulation: Controlling variables (Critical for conducting controlled experiments)	• Struggles to handle or control instruments or resources effectively. • Struggles to adhere to safety guidelines, leading to errors or accidents during experiments.	• Handles or controls most instruments or resources but may encounter occasional difficulties. • Follows most safety guidelines	• Handles or controls a w of instruments or resour effectively. • Adheres to safety guide • Follows established prc accurately and efficient

N	Science process skills (General Interpretation)	Criteria Unsatisfactory *(Lack of skill)*	Basic *(Some skill)*	Proficient *(Good sk*
		• Demonstrates limited understanding of proper procedures for using instruments	• Follows basic procedures for using instruments but may require occasional guidance.	using instruments, mini errors.
10	Interpreting data (Essential for drawing conclusions)	• Struggles to interpret data accurately. • Unable to draw meaningful conclusions. • Unable to support conclusions with evidence	• Interprets data with some accuracy. • May struggle to draw meaningful conclusions • Conclusions may not be supported with evidence	• Interprets data accurate • Draws meaningful conc • Supports conclusion wi

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