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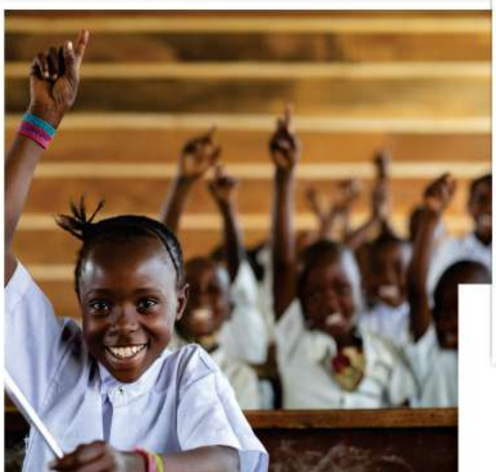
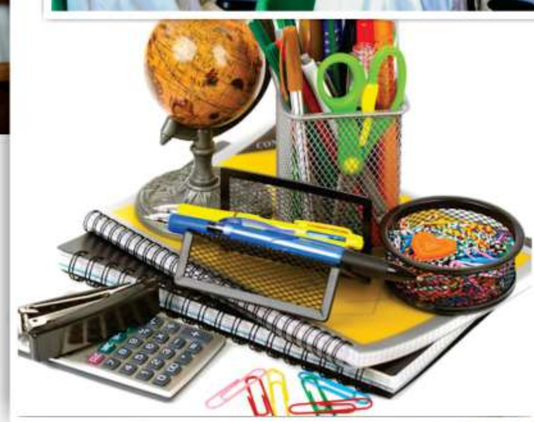
INNOVATIVE STRATEGIES FOR TEACHING VOCATIONAL, SCIENCE, TECHNOLOGY AND MATHEMATICS EDUCATION: CLASSROOM PRACTICES





PROF. JOSEPHINE N. OKOLI

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PREFACE

The electronic book (e-book) acknowledges that traditional methods in Vocational, Science, Technology and Mathematics Education: Classroom Practices may not be sufficient to equip students with the necessary skills for a rapidly evolving technological landscape.

Therefore, it advocates for the adoption of Innovative teaching approaches that promote a more dynamic and effective learning experience.

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FOREWORD

This book entitled "**Innovative Strategies for Teaching Vocational, Science, Technology and Mathematics Education: Classroom Practices",** is a book of readings on various innovative classroom pedagogies. It is a welcome literature for Education System and a very important resource book for teachers who are functioning in the disciplines of Vocational Education, Science, Mathematics and Technology education and training. It is a compendium of most of the **active learning strategies** aimed at producing graduates who have been prepared for adaptation to the conditions of the 21st century world of fluidity. The 21st century world accommodates soft skills which the individual can edit from time to time as the conditions of socio-cultural, economic and technological environments change constantly and uncontrollably. A century in which cross-border job openings are important means of employment, a century where attitude is more important than subject-based excellence, a century where collaboration, innovation and creativity are irreducible demands by employers of labour, a century where adaptive skills are critical for entrepreneurship, creation of jobs and wealth.

All categories of teachers at all levels of education would find this resource book interesting and professionally helpful for their teaching practice. Because conditions of the modern world are in perpetual flux, teachers have to re-skill in order to produce adaptive graduates and the era of lecture method is literally over. It is these modern innovative instructional strategies that would enable teachers to produce such graduates who would survive and then succeed in the 21st century global economy.

This book would also be very useful to researchers and innovators in the envisioned pedagogic paradigm shift of this era. I therefore, proudly recommend this book, a compendium on innovative pedagogies to all classes of teachers and researchers on pedagogies and curriculum reforms in the modern era.

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DEDICATION

This book is dedicated to educators in the world

CHAPTER 17

FROM SUPPORT TO SELF-RELIANCE: INSTRUCTIONAL SCAFFOLDING STRATEGIES FOR 21ST CENTURY SCIENCE CLASSROOMS

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Abstract
One crucial pedagogical strategy that helps students build on past knowledge while progressively gaining learning independence is instructional scaffolding. Scaffolding, which has its roots in Vygotsky's social constructivist theory, can promote student participation, critical thinking, and concept mastery, particularly in 21st-century science classrooms. This chapter explores the role and efficiency of instructional scaffolding in science classrooms, outlines several scaffolding strategies, challenges, and looks at how they affect students' conceptual understanding, independence, and academic engagement. Scaffolding classroom strategies like the use of visual aids, cue cards, handouts, questioning techniques, and prompts are explored along with other types of scaffolding, including conceptual, metacognitive, teacher, procedural, technological, strategic, and peer strategies. Nonetheless, issues including time consumption, inadequate or excessive scaffolding, and the challenge of fading support are recognised. Empirical studies on how instructional scaffolding improves student engagement, critical thinking, and differentiated learning while lowering frustration through scientific experimentation were revealed. Scaffolding also promotes collaborative learning and turns science classrooms into leadership communities where teachers act as mentors and facilitators of knowledge. The chapter concludes with recommendations and educational implications that focused on curriculum redesign, integration of digital technologies, optimised class sizes, and professional development for science educators. This points at the essential for maximising the benefits of scaffolding and achieving meaningful learning outcomes in science education.

Keywords: Self-Reliance, Instructional Scaffolding Strategies, 21st Century Science Classrooms

Introduction

The term scaffolding is frequently used by builders when constructing tall structures, particularly multi-story buildings. Typically, scaffolds are pillars that will support and carry both the building and its constructors. It is employed for scaling extremely tall structures. In education, scaffolding refers to a variety of instructional strategies and support used to progressively increase students' understanding and, ultimately, their degree of independence during the learning process (Doo, Bonk & Heo, 2020). Within a specified time frame, instructional scaffolding gives students the support they need to gain content knowledge and skills. By using scaffolding, the teacher takes on the role of an "activator," helping the student assimilate ideas and develop into a self-aware, independent thinker. In the words of Grimm, Edelsbrunner and Möller, (2023), the foundation of instructional scaffolding as a teaching strategy is the notion that students bring a wealth of prior knowledge to the classroom, some of which may be accurate or misconceived. Using structured support to expand and reshape this prior knowledge is a key objective of instructional scaffolding. In this way, scaffolding turns into an effective teaching tool, particularly in science classrooms of the 21st century, where students are expected to develop collaboration, creativity, critical thinking, and communication skills in addition to learning material.

Science classrooms in the 21st century are defined by dynamic learning settings that incorporate digital resources, inquiry-based methodology, and practical problem-solving exercises. Scaffolding is even more important in a learning environment, as it is dynamic. Teachers must use interactive experiments, data-driven investigations, collaborative projects, and digital simulations to help students learn, all of which can be cognitively challenging. In these situations, scaffolding is crucial for closing the knowledge gap between students and the complex skills required to succeed in contemporary scientific paradigms. Teachers make sure that all students, regardless of background, can access and meaningfully engage with scientific concepts by offering support structures like guided prompts, modelling, technology tools, structured group roles, and formative feedback.

Operationally, instructional scaffolding is a teaching strategy that entails giving students the assistance they require to finish a task or make learning new ideas easier. In the 21st-century classroom, instructional scaffolding entails breaking down difficult assignments into smaller, more manageable components, offering digital resources or templates, and providing thoughtful feedback to direct students' learning. The supports associated with a particular area can be gradually eliminated as the students grow and their skills in that area improve. Students can develop confidence in their skills without experiencing excessive tension or worry by breaking tasks and activities down into manageable bites. The provision of adequate support to encourage learning during the initial introduction of concepts and abilities to students is known as instructional scaffolding. To help students reach higher levels of comprehension and skill development that they would not be able to accomplish on their own, the teacher offers progressively higher levels of short-term support. Resources, an engaging task, templates and instructions, and advice on the growth of social and cognitive abilities are a few examples of these supports. When the supportive tactics are no longer required, they are gradually eliminated, and the instructor gradually gives the students more control over the learning process. Since teachers almost always employ some sort of instructional scaffolding in their lessons, scaffolding is usually regarded as a necessary component of good teaching. Furthermore, learning gaps—that is, the discrepancy between what pupils have learnt and what they should know and be able to do at a particular stage of their education—are frequently filled by scaffolding.

In today’s science education landscape, reducing the negative feelings and self-perceptions that students may have when they undertake a challenging activity without the support, guidance, or knowledge they require to do it is one of the primary objectives of scaffolding. According to Peng and Tao (2022), to apply the scaffolding strategy, a teacher must first identify and ascertain what the students can do on their own and with assistance (i.e., the teacher determines the students' zone of proximal development). To help students thrive in this zone, teachers then modify their support, whether it be through peer collaboration, digital resources, modelling, or questioning.

Scaffolding instruction as a teaching strategy is based on Lev Vygotsky's sociocultural theory and his concept of the zone of proximal development (ZPD). The scaffolding principle is perfect for the technologically integrated, inquiry-driven classrooms of the twenty-first century because it is naturally collaborative and flexible. According to Vygotsky (1978), "the zone of proximal development is the distance between what children can do on their own and the next learning that they can achieve with competent assistance." The tasks provided by scaffolding education are slightly more challenging for the student to complete independently. One important aspect of scaffolding training is the transitory nature of the scaffolds. As the learner's abilities advance, the more seasoned individual progressively removes the scaffolding that is required. At last, the student can complete the task or understand the concepts alone. Therefore, the teacher's goal while using the scaffolding approach to teaching is for the student to become a self-sufficient, independent learner and problem solver. In the long term, scaffolding is more than just a teaching method in contemporary science classrooms; it is an essential link to greater comprehension, scientific literacy, and competency for the future.

Statement of the Problem

Many science classes still mainly rely on conventional (teacher-directed instruction) even though there is a growing emphasis on student-centred teaching strategies, especially in developing nations. When confronted with difficult or abstract scientific concepts, this frequently results in students' passive learning, superficial comprehension and disengagement. Furthermore, in such settings, students with different levels of prior knowledge and learning capacities usually find it difficult to keep up, leading to notable achievement gaps. Although instructional scaffolding is a well-known pedagogical technique for improving student learning, its actual application in science classrooms is still uneven and poorly understood. Teachers' capacity to help students develop inquiry, critical thinking and conceptual mastery is hampered by the absence of clear guidelines on how to implement scaffolding techniques within the context of science education. This chapter delves into the crucial matter of how science teachers can use organised, research-based scaffolding strategies designed for science classrooms of the 21st century to help students transition from teacher-dependent learning to self-reliant inquiry.

Purpose of the Study

Examining the use of instructional scaffolding in science classrooms is the purpose of this chapter. In particular, the chapter seeks to:

1. Analyse the theoretical underpinnings of instructional scaffolding in light of Vygotsky's Social Constructivist Theory, paying particular attention to the functions of the zone of proximal development (ZPD) and the more knowledgeable other (MKO).
2. Describe in detail the different types of scaffolding strategies that are relevant to teaching and learning of science, such as procedural, metacognitive, peer, technological, and conceptual scaffolding.
3. Use visual aids, guided inquiry, cue cards, handouts, questioning, and prompts to illustrate how to implement scaffolding strategies in science education in the classroom.
4. Emphasis how scaffolding can help students in science classes achieve better academically and develop their critical thinking, conceptual understanding and engagement.
5. Discuss the drawbacks and limitations of using scaffolding in science classes, including the fading process, over-scaffolding and time constraints.
6. Make educational suggestions for the successful integration of scaffolding such as curriculum design, science teacher professional development, technology assistance and suitable class sizes.

Lev Vygotsky's Social Constructivist Theory and Instructional Scaffolding

Vygotsky (1978) studied the impact of our social surroundings on learning. According to Vygotsky, learning occurs when students engage with teachers, other professionals, and their peers. As a result, educators can design a classroom that optimises students' capacity to engage with one another via dialogue, teamwork, and feedback. Furthermore, Vygotsky (1978) contends that the main determinant of knowledge production is culture. By engaging with people and adhering to the norms, competencies, and skills established by our culture, we acquire knowledge via this cultural lens. One of the three main tenets of constructivism is Vygotsky's theory:

- Social Interaction: The process of cognitive growth is significantly influenced by social interaction. Vygotsky opined that social learning comes before development. "Every function in the child's cultural development appears twice: inside the child (intra-psychological) and between people (inter-psychological), first on the social level and then on the individual level," he says.
- The More Knowledgeable Other (MKO): Regarding a specific task, procedure, or idea, the MKO is more knowledgeable or skilled than the learner. Though peers, younger people, or even machines could be the MKO, the MKO is typically thought of as an older adult, teacher, or coach.
- The Zone of Proximal Development (ZPD): The ZPD is the gap between a student's capacity to complete an assignment collaboratively with peers or with adult supervision

and their capacity to do so on their own. Vygotsky claimed that this zone was where learning took place and was founded on three principles:

a) Using the Social Constructivist Theory in the design of instruction.
b) Teaching tactics and how they are applied in the classroom.
c) The Social Constructivist Theory's ability to accomplish its objectives.

The first principle calls for an unconventional role for the teacher and students as they work together. For both the teacher and the pupils, learning becomes a mutually beneficial process. The actual classroom would have grouped desks or tables and space for small group education, peer instruction, and collaboration. The classroom thus turns into a leadership community. In order to access the ZPD, the second premise necessitates that scaffolding and reciprocal teaching be successful tactics. Dialogue between the teacher and students is made possible through reciprocal teaching. According to the third principle, Vygotsky's Social Constructivist Theory questions standard educational practices. In the past, recitation instruction has been the mainstay of school organisation. The teacher imparts knowledge for the students to memorise, and they then repeat it back to the teacher.

Just like scaffolding, Lev Vygotsky's social constructivist theory emphasis meaningful interactions between students, teachers, instructional materials, and prior knowledge. As a result, students use scaffolding strategies that encourage participation to build their own knowledge through scientific engagements. Since there is an effective interaction between the teacher and students as well as between the students themselves, instructional scaffolding is a crucial idea in Vygotsky's theory. This interaction ensures that the students are guided within their zone of proximal development and receive support as they advance from reliance to independence in scientific study. By utilising a scaffolding instructional approach, the science teacher establishes a learning context in which students participate in hands-on activities such as experiments, data analysis, and group discussions, which promote meaningful learning. This chapter extensively shows how Vygotsky's Social Constructivist Theory can assist students in developing in social or group settings. Therefore, when students are allowed to participate in inquiry-based tasks with support from the teacher serving as a scaffold, they can develop scientific information independently and develop their cognitive structures.

Types of Scaffolding

Scaffolding are classified into categories based on their function according to Alake & Ogunseemi (2013). They are;

1. **Conceptual scaffolding:** This method breaks things down into manageable chunks to provide students direction on what to think about. For instance, guided pre-service teachers in reflecting on the lesson material using questions.
2. **Metacognitive scaffolding:** With the help of metacognitive scaffolding, students may keep an eye on their own learning, their comprehension of scientific assignments, and their time management. Simply put, develop self-regulation and self-monitoring skills.
3. **Teacher scaffolding:** The teacher serves as a support to the students through methods like modelling, demonstration, and provision of feedback.
4. **Procedural scaffolding:** Using a methodical approach or procedure, procedural scaffolding teaches students how to use the materials and equipment offered in the classroom.
5. **Technological scaffolding:** Here, digital tools such as videos, online tutorials, educational Apps, and interactive stimulations are utilized to provide support to the learner.
6. **Strategic scaffolding:** Strategic scaffolding offers learners a repertoire of alternative techniques and tips where they develop problem-solving skills and evaluate outcomes.
7. **Peer scaffolding:** In peer scaffolding, the students work together and provide support to themselves through group learning/work, peer tutoring, and collaborative learning/projects.

Instructors may use one type of scaffolding or a combination of two or more to achieve learning outcomes and promote learning independence (Petersen, 2022).

Scaffolding Strategies for Students and Teachers in the Science Classrooms

Students must apply scientific methods, engage with complex concepts, analyse data, and work well in teams in the science classroom of the twenty-first century. Scaffolding techniques are crucial for leading students through progressively difficult cognitive tasks in order to meet these expectations. Below are effective scaffolding strategies that enhance understanding and learning outcomes in science instruction:

1. **Use of visual aids:** The use of charts, pictures, graphs, and slideshows serves as visual tools to provide the students with the needed opportunity to see or have a virtual representation of what is learned. It helps in providing guidance, support, and understanding of difficult scientific ideas and ensures students' learning and retention (Alber, 2014).
2. **Graphic organisers:** Here, difficult or abstract concepts are explained using tables, number lines, charts, graphs, and infographics, which serve as scaffolding tools. It provides visual guidance to learners, shapes their thinking, and enhances the visual representation of scientific ideas.
3. **Modelling (Show & Tell):** As an effective scaffolding strategy, the teacher solves a problem in front of the students while they watch and asks them to model the steps used in arriving at the answer. The teacher is expected to demonstrate what the students are to do and the possible outcome of the activity before they model it. The use of a criteria chart or rubric is encouraged in this process.
4. **Cue cards:** The teacher prepares the cards relating to a particular learning objective and gives them to individual learners or groups of students. This will aid direct discussions in the classrooms. Cue cards can be written or visual prompts that guide the students through a task. It can include lab safety procedures, steps in the scientific method, scientific terms, or key formulas.
5. **Handouts:** Here, the handout material serves as a scaffold containing information on a topic, prepared with less detail and a space for notetaking. The material must also contain tasks related to the content of the study objects to enhance scientific exploration.
6. **Prompts:** This is used as an aid to recall prior knowledge. It can be a verbal or physical prompt. In verbal prompts, questions, words, and statements are used as a scaffold, while in physical prompts, body movements like eye blinking, foot tapping, pointing, and nodding the head are used. Visual prompts can also be used in scientific inquiry using photographs, videos, and drawings (either on paper, a whiteboard, or an electronic device).
7. **Questioning techniques:** Here, the teacher uses open-ended questions such as (Why do you think this reaction occurred?) to encourage and promote critical thinking and discussions among learners.
8. **Advance organisers:** These are resources/tools used to improve students' understanding of a subject and present new material. The scaffolding tools used here are mnemonics (to memorise classifications such as taxonomy and enhance recall), Venn diagrams (used to compare & contrast information), statements to situate the task or content, flow charts (illustration of processes like nutrient cycles and photosynthesis), rubrics (for provision of task expectations and lab reports), and organizational charts to illustrate hierarchies.
9. **Building on students' prior knowledge:** The teachers use examples that students are familiar with in making connections to concepts, especially in complex lessons. Additionally, the teacher can ask the students to apply the topic to their own lives by asking them to share their thoughts and personal experiences. The teacher can also provide hints or suggestions in the process. For instance, local weather patterns can be used to start a conversation about climate change, or cooking or rusting metals can be used to illustrate chemical reactions. This serves as a good teaching method and not just an instructional scaffold.
10. **Read aloud:** This is used to check the understanding of students when reading difficult scientific texts. Here, the instructor presents a novel concept from the text, gives students time to reflect, and then poses questions before stopping once more for review and responses. This

strategy is effective when introducing new information from science journals, textbooks, or articles on current scientific advancements.

Furthermore, according to Firestone (2015), the following are the step-by-step guidelines for the effective implementation of the various instructional scaffolding strategies: Before expanding on that understanding, a teacher starts by teaching at a level that the students can comprehend. After that, the instructor poses the issue and thinks aloud while they attempt to resolve it. In the process, the instructor demonstrates how to use language, visuals, and actions to arrive at a solution. Next, the instructor does the following:

- Ask the students questions while you go through the previously outlined procedures again.
- In order to promote involvement, make sure that every response, correct or incorrect, gets a good response.
- Students should be encouraged to answer questions.
- When necessary, offer corrections while providing encouraging reinforcement.
- When comprehension seems to have been attained, students assist the teacher in resolving a fresh issue.
- As they work through difficulties, their comprehension is examined. There is additional modelling available if more instruction is required.
- If students show that they understand the material, they fade, or move aside, and let them work on their own while providing assistance as needed.

Guidelines for Implementing Instructional Scaffolding

When putting instructional scaffolding into practice, the following ideas might serve as guidelines.

- Choose appropriate assignments that align with students' requirements, course learning objectives, and curricular goals.
- Let students contribute to the creation of learning objectives; this will boost their enthusiasm and dedication to the subject.
- When evaluating pupils' progress, take into account their backgrounds and past knowledge; too simple content can rapidly bore students and sap their motivation. Conversely, overly challenging content can deter pupils' interest levels.
- As students move through a task, employ a range of supports, such as questions, prompts, hints, stories, models, and visual scaffolding, which includes diagrams, representational gestures, pointing, and other techniques for emphasising visual information.
- Assist students in staying focused on the objective, allow them to ask questions, ask them to explain their progress, and offer support and praise.
- Use feedback to track students' progress. In addition to instructor comments, ask students to list their accomplishments so they can see where they are and where they still need to go.
- Establish a friendly, secure, and encouraging learning atmosphere that inspires students to try new things and take chances (everyone should feel free to voice their opinions without worrying about unfavourable reactions).
- Encourage students to practise the task in many contexts and assist them in becoming less reliant on instructional supports as they do it (Hogan and Pressley as cited in Northern Illinois University,2012)

The following are the tools that facilitate the successful implementation of instructional scaffolding:

- Divide the work into more manageable, smaller components.
- When finishing a task, articulate your thought processes by using "think-aloud."
- Facilitate peer communication and teamwork by implementing cooperative learning.
- Activate prior knowledge and provide advice, techniques, signals, and protocols as additional tools.

- Use tangible prompts, questioning, coaching, cue cards, or modelling (Lipscomb, Swanson, and West as cited in Pinantoan, 2013).

Students can freely ask questions, offer feedback, and assist their peers in learning new content in a scaffolded learning environment. Instead of being the primary subject matter expert, the instructor takes on the role of mentor and knowledge facilitator. Students are encouraged to participate more actively in their own education via this teaching method, which raises their interest and achievement. Through scaffolding that requires them to advance beyond their current skill and knowledge levels, students share responsibility for science teaching and learning and take charge of their learning experience through this engagement (Northern Illinois University, 2012).

Benefits of Instructional Scaffolding

According to Pinantoan (2013), instructional scaffolding is a teaching strategy that gradually reduces the amount of outside help needed for a student to complete a task, solve an issue, or reach an objective. Pinantoan further asserted that instructional scaffolding;

- Encourage increased confidence that the student will acquire the needed aptitude, knowledge, or skill.
- Offers education that is differentiated.
- Enhance the effectiveness of instructional delivery
- Develops critical thinking and problem-solving abilities/skills
- Creates momentum
- Engages the learner and
- Lessens the student's degree of frustration

In addition, Northern Illinois University (2012) demonstrates that educational scaffolding

- Pushes pupils via in-depth study and exploration
- Encourages students to participate in lively and significant conversations in both small and large courses.
- Encourages students to improve as learners (learning how to learn).
- Boosts the possibility that pupils will achieve learning goals
- Offers tailored and customised instruction.
- Provides the chance for studying and teaching among peers.
- Offers a warm and compassionate educational setting, thereby boosting students' confidence, interest, retention, and learning outcomes.

Challenges of Instructional Scaffolding

The challenges associated with instruction scaffolding include:

- **Time-Consuming:** The preparation and implementation of instructional scaffolding is time-consuming and demanding. As instructional scaffolding requires intensive efforts from the teacher to be successful.
- **Lack of examples and tips:** Textbooks in use may not have provided enough guidance or examples for the effective implementation of scaffolds in a topic (Callo, 2025).
- **Difficulty in fading scaffolding support:** Determining the right time to remove support can be tricky, as it takes skills and practice to know when the students are proficient in the lesson content and can work independently of anyone. (Staake, 2024)
- **Lack of trained teachers:** To effectively plan and deliver scaffolding requires skilled and experienced teachers who are technically sound, and when this is not met, it becomes a challenge.
- **Under-/Over- Scaffolding:** Providing inadequate or too much support to the students can negatively affect students' understanding, motivation, and interest, leading to frustration, poor students' learning autonomy, and low confidence.
- **Adapting to individual differences:** The ability to meet the various needs of individual learners can be challenging. This is because students learn and process information

differently. Hence, the learning styles, needs, and abilities need to be considered during the planning and implementation processes.

- **Lack of access to learning resources:** The effective implementation of scaffolding requires adequate access to technologies, instructional materials, and personnel, which can be a challenge if not available.
- **Sustaining motivation:** Scaffolding may not effectively engage all the students at the same time, which could invariably affect their motivation in learning.
- **Size of classes:** The size of each class minimises teachers' ability to identify the zone of proximal development of each learner, thereby minimising students' demand for one-on-one engagement, which could affect their learning outcome.
- **Over-reliance on scaffolding tools:** When a teacher fails to remove the scaffolding tools appropriately and gradually, the students may become over-reliant on the tools, which can affect their learning and ability to develop learning skills.

Insights into Some Empirical Studies on Instructional Scaffolding and Science Subjects

The study of Ezeudu, Nwafor, Abaeme, Alabi, Chukwuka, and Ikuelogbon, (2019) on the effects of scaffolding as an instructional strategy on students' chemistry achievement and interest indicated that, in contrast to the traditional approach, scaffolding significantly affects students' interest and achievement, whereas gender had no discernible impact on the average accomplishment and interest scores of chemistry students.Using tertiary students in South Africa, Bertram, Johnson and Goldring (2022) conducted a study on how the use of scaffolding academic literacy practices affects them in the classroom. The findings showed that scaffold academic literacy practices enhance students' reading, writing, and engagement, and provide an educational approach to plagiarism by modelling how to paraphrase academic texts. The concept of photosynthesis is taught in secondary school science classes using scaffolding, which improves student comprehension and engagement through diagrams, easy experiments, and structured questions (Belland, Walker, Kim and Lefler, 2017; Pol, Mercer & Volman, 2018). Alrawili, Osman and Almuntasheri (2022) reported a significant difference in the attitudes of science students in a Saudi Arabian study between those who were taught using scaffolding strategies and those who were taught using traditional teaching methods. It further suggests the application of the strategy in science classrooms as it both directly and indirectly enhances independent learning and develops students' positive attitudes towards learning science. Through creative problem solving and specially designed scaffolding learning, students' capacity for scientific thinking was enhanced (Ratnasari, Suciati, & Maridi, 2019). The following strategies were specifically used to help students improve their inquiry, analysis, inference, and argumentation skills: environmental provisions, mess finding, fact finding, problem finding, explaining, reviewing, and restructuring, idea finding, solution finding, developing conceptual thinking, and action finding. According to Acosta-Gonzaga and Ramirez-Arellano (2022), metacognitive involvement has a direct impact on cognitive engagement. Cognitive engagement influences learning engagement, and motivation is the catalyst for all of them. Scaffolding also improves emotional involvement. Students who receive support from their teachers are more likely to be excited, engaged in class, enthusiastic during learning activities, and pleased with their academic achievements. Scaffolding aids students in comprehending fractions and relating abstract ideas to tangible representations in elementary school mathematics classes (Ikawati, 2020; Rindengan & Rindengan, 2019). Furthermore, Kusmaryono and Wijayanti (2020) report on the impact of scaffolding on learning outcomes in mathematics courses. The effects of reflective (i.e., meta-cognitive) and supporting (i.e., conceptual) scaffolding on learning outcomes and problem-solving performance in online ill-structured problem solving in Korea were compared by Kim & Lim (2019). The findings showed that in terms of learning outcomes and problem-solving abilities, the reflective scaffolding group fared better than the supportive scaffolding group. Additionally, the authors discovered a noteworthy interplay between the meta-cognitive effects in an online learning environment and the kind of scaffolding used. A recent systematic literature review by Azzaroiha, Redhana and Suma (2025) revealed that scaffolding has a positive effect on students' misconceptions, scientific literacy, problem-solving abilities, concept understanding, science process skills, argumentation skills, critical thinking skills, higher-order thinking skills (HOTS), learning independence, and motivation. Problem-Based Learning (PBL) is another popular learning model that is utilised alongside scaffolding. The researchers concluded that it is possible to enhance science learning using scaffolding strategies. A study conducted by Immelman, Carstens, Smith and Masenge (2020) carried out in South Africa using tertiary students revealed that students are enthusiastic about the use of concept mapping as a scaffolding strategy, though no conceptual understanding was established. In the Otuocha education zone of Anambra State, Nigeria, Anyanwumelu and Okigbo (2022) examined the impact of the scaffolding instructional technique (SIS) on the interest of secondary school pupils in mathematics. The results showed that, in comparison to the traditional lecture method, the use of SIS in the classroom considerably raised the interest scores of SS2 students in geometry. Additionally, when geometry is taught with SIS, gender significantly affects pupils' general interest in the subject, favouring male students. In a different study, Omiko (2015) examined how instructional scaffolding affected the chemistry proficiency of secondary school pupils in Ebonyi State, Nigeria. The analysis's findings showed a substantial difference favouring the scaffolding group between the study's experimental and control groups. In favour of the males, there was also a notable disparity between the two sexes. On the other hand, the mean retention test did not show any significant interaction between gender and teaching technique. The study found that scaffolding had a major impact on students' achievement in chemistry. In another study by De Jager (2019), it was found that the use of differentiated assignments as scaffolding methods has a positive influence on first-year student teachers' academic success and lecturers' evaluation styles in a South African University. In the Owerri Municipal Council of Imo State, Nigeria, Ihechukwu (2020) investigated the effect of instructional scaffolding on mathematics students' achievement. According to the study's findings, mathematics students who were taught utilising an instructional scaffolding approach performed better than those taught using the traditional approach. Among other things, it is suggested that instructors use instructional scaffolding as a teaching strategy, as it also minimises gender bias.

Educational Implications of Instructional Scaffolding in Science Classrooms

1. Instructional scaffolding helps science students comprehend a variety of academic concepts and make efficient progress towards their learning objectives. They are motivated to learn and actively participate in the learning process.
2. As students continue to advance, it can be utilised to rectify their mistakes and clear up misconceptions, which will promote learning (Ugwumba & Kodjo, 2015).
3. With their help, teachers may establish a more science-conducive learning atmosphere where students can engage with the course materials and their classmates to identify and address their academic requirements.
4. By using instructional scaffolding, science students can be given the tools they need to improve their memory as well as become successful learners in the classroom. This improved memory capacity would help children avoid rote memorisation and prepare them to be self-directed learners for the rest of their lives.
5. The usage of scaffolding stimulates science students' interest by igniting their curiosity. Scaffolding can therefore be utilised to increase students' academic performance and enthusiasm for scientific exploration.
6. Examination bodies, curriculum planners, and policy makers should organise textbooks and curricula to foster students' enthusiasm, attitude, and scientific knowledge beyond the classroom.

Conclusion

Students can better understand a range of academic subjects and move more quickly towards their learning goals, particularly within the science classroom, with the aid of instructional scaffolding. Because abstract concepts, technical terms, and practical (hands-on) experimentation can be very difficult in science classes, scaffolding techniques give students the help they need to clear up misunderstandings, fix errors, and develop a strong foundation of knowledge. Teachers, while integrating scaffolding into the science classroom, can create a supportive and interactive learning environment where students can interact with the course materials and their peers to determine and meet their academic needs by using instructional scaffolding. By arousing students' curiosity and improving their academic performance and zeal for learning, scaffolding stimulates their attention in science subjects. Students' interest and performance increase as a result of being encouraged to take an active role in their own education. Students can take control of the learning process by sharing responsibility for teaching and learning using scaffolding tools. Therefore, curriculum developers, policymakers, and educational planners should create science textbooks and curricula that incorporate scaffolding strategies and encourage inquiry-based learning. In addition to improving retention and understanding, this will foster a lifelong interest in science in students, preparing them to succeed in the rapidly changing scientific and technological environment of the 21st century.

Recommendations

The study recommends that;

1. **Development of Curriculum**: Learning institutions should create curricula that prioritise scaffolding techniques and integrate the concept of instructional scaffolding within science lessons.
2. **Mentoring and Demonstrations:** To ensure that students comprehend all of the learning concepts and objectives, teachers should use mentoring and demonstrations as scaffolds. This can be accomplished by guided experiment, modelling of scientific investigations/processes, and assigning inquiry-based projects to students based on the curriculum.
3. **Integration of Technology:** The introduction of technology into the science classroom should be a powerful scaffolding tool. This can be accomplished through interactive simulations, digital tools, virtual science labs, and government-sponsored research that promotes experiential learning in science.
4. **Provision of Instructional Resources:** Teachers and students should be equipped with instructional resources, including presentations, audio, digital simulations, and educational videos to help them better meet the demands of teaching and learning, and ultimately meet the educational goals and simplify abstract scientific concepts.
5. **Focus on the Zone of Proximal Development (ZPD):** Since the ZPD helps teachers adjust scaffolding strategies to students' readiness levels, it should receive more attention in science education. This method encourages the steady mastery of difficult material in courses like biology, chemistry, and physics.
6. **Class Size and Learning Environment:** Educators and administrators should ensure that science classrooms are spacious and maintain small class sizes to enhance scaffolding through personalised learning, hands-on experiments, inquiry learning and teacher-student interactions. They should be large enough and have small enough class sizes so that teachers can employ efficient scaffolding strategies.
7. **Infrastructure Development:** Government and stakeholders should prioritise the construction and equipping of science classrooms and laboratories to enable the practical application of scaffolding through experimentation.
8. **Teacher Training and Professional Development:** Science teachers and pre-service teachers should participate in continuous training or staff development programs through seminars and conferences to stay updated on modern scaffolding strategies.

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