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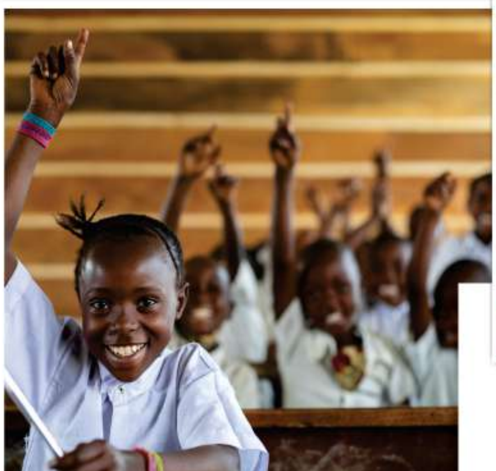
INNOVATIVE STRATEGIES FOR TEACHING VOCATIONAL, SCIENCE, TECHNOLOGY AND MATHEMATICS EDUCATION: CLASSROOM PRACTICES



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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 13

INNOVATIVE INSTRUCTIONAL STRATEGIES IN SCIENCE TEACHING AND LEARNING

John B. Moses
Tamaraudeinyefa Tobi

Abstract
This article examined innovative instructional strategies that could be used in science teaching and learning. The strategies were grouped into two. They are; the non-digital innovative instructional strategies which included, concrete representational abstract, problem solving strategies, retrieval-based learning, gamified learning and the digital-based innovative instructional strategies which included, flipped classroom strategy, mobile learning app strategy, virtual manipulative strategy and virtual laboratory strategy. It was recommended that teachers and learners should use innovative instructional strategies to enhance the teaching and learning of science.

Keywords: Instructional Strategies, Science Teaching and Learning

Introduction

Instructional methods or strategies are the backbone of the success of the teaching and learning process. It shapes how knowledge is conveyed and absorb. Choice of instructional strategies is especially important in science education, as it is characterised by complex and abstract concepts, as well as require a great deal of critical thinking.

The instructional strategy used actively influences the learning outcomes, including students' engagement, comprehension and knowledge retention. Classroom science instructional has long being dominated by traditional teaching approaches such as lecture-based instruction and rote memorisation. However, the limitations of these strategies has over time come into light, and are increasingly being challenged by the need for more dynamic, interactive, and student-centred learning experiences.

Several innovative instructional strategies have been introduced and explored over time to circumvent the limitations of traditional instructional methods. Most innovative instructional strategies in recent years have revolved around the incorporation of digital technologies into the instructional process. This trend is tied to the rapid evolution of technology which has introduced ground-breaking innovations and tools that can be applied into the educational process.

Other than these digital-based innovations in instructional strategies, there exists several non-digital instructional strategies which remain highly effective in fostering meaningful learning.

This article thus, explores some of the innovative instructional strategy in science education. Here, the non-digital and the digital instructional approaches are examined. By exploring and integrating these approaches, science teachers could provide a richer and more meaningful learning experience for the students.

Statement of the Problem

Science teaching and learning are integral parts of the secondary school programme in Nigeria. The basic science subjects such as biology, chemistry, physics, basic science and mathematics are characterised with the problem of low achievement. This problem has been blamed on a lot of factors which included the methods used in the teaching and learning of science. Some of these methods used have led to the learners learning science by rote. This now calls for the need for the introduction of innovative instructional strategies that could lead to a better achievement of the learners in science. Hence this article examined innovative instructional strategies in science teaching and learning.

Purpose of the Study

This article examined innovative instructional strategies in science teaching and learning. Specifically, the article examined;

i) non-digital innovative instructional strategies.

ii) digital-based innovative instructional strategies.

Non-Digital Innovative Instructional Strategies

Some non-digital innovative instructional strategies are highlighted below

Concrete Representational Abstract

Concrete representational abstract is an instructional approach heavily based on multiple representations and characterized by the provision of hands-on experiences for the students. This approach is primarily designed for mathematics teaching and learning, though could be applied to problem solving in other subjects. Moore (2020) states that the concrete representational abstract is an evidenced based strategy that has been proven to be effective in increasing students' knowledge and skills.

The concrete representational abstract sequence is a three step process that involves the students learning to move from concrete application to abstract application (Lemondis, Anastasiou, & Iliadou, 2020). . The stages can be said to be concrete, representational, and the abstract stage, in line with the name of the strategy. Description of the three phases, as explored by Moore (2020), Milton, Flores, Moore, Taylor and Burton (2019) and Apule, Ishizaka & Chikamori, (2018) are given below;

In the concrete phase the students forms and develops conceptual understanding through the manipulation of physical objects. The representational stage involves the use of simple illustrative or diagrammatic representation of concrete objects manipulated by students at the first level. At this stage, the students utilize or create pictorial representations of concepts (usually representation of the objects they previously manipulated) to learn. The abstract stage is the final in the sequence, and involves the storing of information related to representations in symbols. Here, the students learn through the use of numbers and symbols to represent objects, without the aid of physical objects or representations. It is the typical route/format of mathematics learning, and is what is often referred to as "doing mathematics in your head" (Apule et al., 2018).

The whole concrete representational abstract model can be demonstrated using an example of teaching counting and addition to elementary school pupils. To apply this model, the teacher will first provide the students with a manipulative like counting sticks or chips. The teacher teaches the students how to combine different amount of counting sticks or counting chips to solve addition problems, (concrete stage). Once that is mastered the teacher can then guide to draw vertical lines to represent sticks, or small circles for chips, to represent the integrals which need to be added, and then they count the drawn objects to get the answer, similar to the technique used earlier (representational stage). Once that is mastered, instruction can then move to the abstract stage, where all problems and solutions are done using actual numbers, without the aid of manipulative or representations (abstract stage).

Problem Solving Strategy

The problem solving approach otherwise known as teaching through problem solving, is an instructional technique that originates from and primarily designed for adoption in teaching and learning concepts in mathematics, though its principles can be applied and utilized in other fields of study. As the name implies, this strategy is primarily oriented towards the solving of problems.

The problem solving approach is a student-centred instructional strategy, centred on using higher-level thinking, and engaging in an inquiry-oriented environment. It is a method of learning where the learning of new concepts is the result or outcome of a problem solving process (Toh, 2022).

The problem solving approach enables the students to explore problems by themselves and develop solution strategies from their own experiences (Bullock, 2017; Russo, Palomino, Toda, Klock, Oliveira, Avila-Santos, Gasparini, I. & Isotani, 2020).

Applying the problem solving approach in the classroom situation typically occurs in a number of steps, which can be categorized into phases of launch, explore and summarize. In the launch phase, the teacher presents to the students, a problem that is cognitively demanding and related to their prior knowledge. The teacher at this stage, does not give answers to the students, but instead suggests a possible pathway to solve the problem, building up on their existing prior knowledge or what has been learned before. (Alwarsh, 2020; Pyler, 2018). Next comes the explore shade, where the students start the quest of finding solutions to the problem of interest either individually or in groups. The teachers oversee the whole process, while planning for the summary phase, by monitoring students' ideas and thinking patterns (Laine, 2018).

In the summarize phase, the teacher tasks the students with sharing their solutions, and the strategies utilized in arriving at that solutions. The teacher guides the students in connecting and comparing the different strategies they have used in arriving at a solution, noting which are easier, correct, similar to each other, more efficient, etc. (Sionicion & Barbacena, 2021; Takahashi, 2021). The class discussions at this phase are especially important as it encourages the students to reason and share perspectives, ideas, and rationales behind solutions, among others.

Alwarsh (2020) states that the research findings on the use of problem solving approach to teaching, has largely being positive, and promising as a base for reform in curriculum and instruction. This strategy is beneficial for building up students' problem solving skills, enhancing critical thinking and questioning skills, and learning to conduct inquiry (Stacey, 2018).

Retrieval-Based Learning

Retrieval-based learning is an educational technique, centred around the promotion of long term retention of knowledge. It is otherwise known as repeated recall or test-enhanced learning. Retrieval-based learning is drawn from the idea that a student providing accurate answers to a question will lead to a higher probability of retaining that answer. In retrieval-based learning, the retaining of knowledge is enhanced by the learner constantly retrieving or recalling what has been previously taught (Perry et al., 2021).

Larsen (2018), Yang, Luo, Vadillo, Yu, & Shanks, (2021) describe learning facilitated by retrieval to be quite effective in mastering and retaining learned concepts, such that it is deemed even more powerful than constantly re-reading or restudying a concept. Retrieval-based learning can be done during the classroom instructional process, and even in the students' personal study times. It often involves the use of low stakes assessments, that will require the learner to think about what they have learned, for them to provide the answers (Stills, 2022). The low-stakes assessments used in repeated recall are meant only to engage the students, to recall what they have previously learned, and are not meant to be scored for recording.

Selecting an appropriate level of difficulty (desirable test difficulty) for the low stakes assessment in retrieval-based learning, is of major importance, and can make or break the process. Lyle, Bego, Hopkins, Hieb, & Ralston (2020), Minear, Coane, Boland, Cooney & Albat (2018) states that difficult but successful retrieval sessions, are likely to be much more beneficial for long term knowledge retention, than easier retrievals. The retrieval-based learning is likely to be more successful in a test where the students have to recall the correct answer from their memory and write it down, rather than a test where they just have to pick the correct answer from a list of options (Yang et al., 2021). On the other end of the spectrum, the tests utilized in retrieval sessions, shouldn't be too difficult, as this will likely to turn the student off the use of such tool, or that the students become unable to recall nothing. (Sumeracki & Weinstein, 2018).

The continued use of recall of learned information in retrieval-based learning is deemed not only beneficial in academic contexts but also in vocational area centred on skills and their acquisition. Like how a tailor is likely to get better at their field the longer they are in it, because they constantly have to recall what they have learned, which in turn leads to increased mastery in their fields.

As retrieval-based learning involves the regular recall of learned information (which is usually done using assessments), attention must be paid on how retrieval sessions (or tests) are spaced out. Latimier, Riegert, Peyre, Ly, Casati and Ramus (2021) states that, the nature of content being learned must be greatly considered, when deciding or determining the frequency or the time-frame for retrieval sessions in retrieval based learning. They suggest that for an effective retrieval-based learning, the period between learning the content and the retrieval session needs to be short for difficult concepts, and longer for concepts that are deemed much simpler. Donoghue and Hattie (2021) states that it is the appropriateness and effectiveness of the actual assessment tool used in retrieval sessions that matters the most, way more than the interval between retrieval sessions.

Gamified Learning

Gamified learning is an innovative instructional strategy centred around the introduction and integration of game elements and mechanics into learning environments (Christopoulos & Mystakidis, 2023). It involves incorporating diverse elements such as leader boards, challenges, badges, and points along others. Thus, through this, the learning experience is transformed and made more interactive and enjoyable.

While the title might suggest otherwise, gamified learning does not involve using video games for instruction, but rather just applying game like elements in educational contexts (Landers et al., 2017). This approach leverages human psychology, particularly intrinsic and extrinsic motivation, to foster engagement. That is, the goal of gamified learning is not merely to entertain but to leverage the psychological and motivational aspects of games to make learning more enjoyable, immersive, and effective (Christopoulos & Mystakidis, 2023).

A successful gamified learning strategy is comprised of some key elements, some of which includes: clear goals and objectives (that align with educational outcomes), challenges and levels (for learners to progress through mirroring that of video games), points and rewards (to reinforce achievement), leader boards and friendly competitions, provision of immediate feedback, storytelling (which enhances immersion and investment in the learning experience), and personalisation and adaptability (Wulan, Sulistiadi, Nugraha, Rohman, & Fiyul, 2024).

Gamified learning is beneficial for a wide variety of reasons. Among others, it can lead to increased engagement in learning (Wulan et al., 2024). This is because gamification taps into man's natural desire for achievement, progress, and competition, making learning more enjoyable, furthermore, games are inherently engaging, and incorporating their elements into learning can capture students' attention and sustain their interest.. Being a student centred approach that heavily emphasises interactive and immersive elements; the gamified learning can also lead to improved knowledge retention (Putz, Schmidt-Kraepelin, Treiblmaier & Sunyaev, 2018). Gamified learning can also foster the development of problem solving skills and critical thinking. The rewards and recognition systems involve in gamification can also foster and sustain learner's motivation to learn even in challenging subjects (Alsawaier, 2018). Gamified learning also supports personalised learning (Rodrigues, Palomino, Toda, Klock, Oliveira, Avila-Santos, Gasparini, & Isotani, 2021).

Some best practices that has been recommended for gamified learning includes: define clear learning objectives and outcomes, use of meaningful rewards, establish a balance between fun and educational value (particularly ensuring that the entertainment does not overshadow learning), encourage and facilitate collaboration, provision of continuous feedback, among others (Christopoulos & Mystakidis, 2023; Fuchs, 2024).

Digital-Based Innovative Instructional Strategies

Some innovative instructional strategies centred on the use of digital technology to support teaching and learning are highlighted below:

Flipped Classroom Strategy

Flipped classroom strategy is an instructional approach that has gained attention in recent years. As an instructional model, it reverses the traditional teaching process. Here, instead of delivering lectures in class and assigning homework for practice, educators provide students with access to instructional materials, such as pre-recorded video lectures or reading assignments, to review before class (Cabi, 2018; Chen, Chao & Hung, 2018). Class time is then dedicated to interactive activities, discussions, and problem-solving exercises that reinforce and apply the concepts learned independently.

The flipped classroom strategy involves alternating the locations of typical classroom activities (like lectures) and the homework for those activities (like individual reading or practice problems) (Ajimal & Muhammed, 2021; Gong, Zhang, Wu, Tian, Wu, & Zhang, 2018). In the flipped classroom strategy, students are first exposed to new learning materials and content outside the classroom, typically using information and communication technology (ICT) resources. Then, class time is used for more hands-on activities, usually emphasising collaboration. Exercises and discussions typically take up the majority of the class time. During class time, the teachers are free to function as facilitators who enhance the learning environment since they are no longer expected to provide all the materials and serve as knowledge reservoirs in the flipped classroom paradigm.

The process involved in adopting a flipped classroom can be outlined into three stages: pre-class preparation, in-class activities, and post-class assessments (Mclean & Attardi, 2018; Prust, Kelnhofer, & Petersen, 2015; Rotellar and Cain, 2016; Samarrie et al., 2020). At the pre-class stage, the teacher presents the learning materials (which may include recorded videos, audio, texts, etc.) to the students, which the students are expected to learn before class to get foundational knowledge and exposure. In-class activities are the actual class time, which is used for active learning experiences and a range of learner-centred activities such as group discussions, problem-solving activities, hands-on projects, learning exercises, and guidance from the teacher. This stage of the flipped classroom is geared towards making pre-class material more understandable and increasing knowledge and retention in the classroom. Post-class is then used for further assessment and feedback; however, it is not used in every flipped classroom process.

Benefits of this strategy includes its support for personalised learning (Cevikbas & Kaiser, 2022), increased engagement and motivation in learning (Jdaitawi, 2019), improved interpersonal relationships and cooperation in the classroom, which is the cornerstone of collaborative learning (Kwon & Woo, 2018). The flipped classroom strategy is also beneficial heavily student-centred and oriented nature.

Mobile Learning Apps Strategy

The mobile learning apps instructional strategy is an innovative approach to classroom instruction. Mobile learning as used in this context involves the use of mobile devices for classroom instructional/educational purposes. Mobile device is quite a popular piece of computer technology, such that it is quite rare to see an individual without one. The development of mobile device has experienced a steady growth through the years, and has become so interwoven with many everyday activities (Kilmova & Poulova, 2016; Melo & Como, 2016).

Mobile apps refer to those forms of application software, designed to work on mobile devices. On the basis of this, mobile learning apps refer to all manners of mobile apps, which cover educational content in its framework, and is usually designed to aid the learning process. Mobile learning apps covers a broad scope, that cut across differing contents and designs and even formats including texts, videos, e-books, audio books, interactive quizzes among others (Raouna 2021). Popular mobile learning apps include Cousera, Udemy, Khan Academy, Quizlet, Sololearn among others. Applications like YouTube, though not primarily designed for educational purposes, can still act like a mobile learning app, due to holding a wide variety of useful educational content in its platform (Deans, 2021).

The mobile learning apps instructional strategy holds a number of potential benefits for the learning process. It is beneficial for enhancing the achievements of students and their learning outcomes. The mobile learning apps instructional strategy also provides for the students a much richer experience in the learning process, by taking advantage of the various tools and resources available within the body of mobile devices (Ansari & Tripahti, 2017; Chiang, Yang & Yin, 2019). The mobile instructional strategy in subjects, facilitates better assess to instructional tools and resources including study aids, and even instructional approach.

The use of this innovative approach to teaching also provides opportunity for the employment of varied methodologies into the teaching process, hence presenting the teachers with more effective ways to carryout teaching like the inclusion of elements of discovery, inquiry, collaboration etc. (Nastution & Siddik, 2020). The mobile learning apps instructional strategy tends to also be cost-saving, especially in relation to other pieces of computer gadgets that can be used for e-learning. It is also characterized by an increased flexibility and mobility (Morris, Lambe, Cicconet, & Swinnerton, 2016).

This strategy also leverages on the simplicity and easy access that characterise mobile phones. The communicative features available in mobile devices can also help in building up collaborations and interactions amongst the bodies in the learning experience (Celik & Yavuz, 2018; Uther, 2019). Ansari and Tripathi (2017), cited some of the most important benefits of utilizing mobile apps into teaching as including; the support for individualized learning, decline of the limitation of physical classrooms to carry out teaching-learning activities, enhancements of communication and thus collaborations and active engagements, support for easy sharing of resources and learning materials, provision for more interest igniting patterns of instruction, among others.

Virtual Manipulative Strategy

Virtual manipulative strategy is an innovative approach to teaching that is mostly used for mathematics instruction. Moyer-Packenham and Bolyard (2016), defined virtual manipulative as an interactive visual representation of a dynamic mathematical object, including features which can be manipulated, and which can be utilized in constructing and concretizing knowledge. The major distinguishing factor of virtual manipulatives from other forms of technology-based learning resources/tools is the provision for interaction of the virtual manipulative user with the dynamic object, such that these interactions create the actual framework and opportunity for learning.

Virtual manipulatives are typically digital representations/computationally enhanced versions of physical manipulatives/objects, and can be manipulated (through computer mouse, or finger on a tablet) to move, rotate, transform or flip (among others) usually in the same manner like a real life three-dimensional object (Oryxlearning, 2021).

Benefits associated with the use of virtual manipulatives strategy includes: acquisition and maintenance of understanding of concepts and enhancement of students' achievement and independence (Bouck, Satsangi, & Park, 2019; Bouck, Chamberlain & Park, 2017); bringing learning conditions to a desirable environment, engaging, and more fun environment (LoVerde, Kerber & Jenkins, 2019; Shin, Bryant, Bryant, McKenna, Hou & Ok, 2017).

Virtual manipulatives for the teaching and learning are associated with increased options for flexibility as the technology are dynamic and ever evolving and can be tailored to the needs and capabilities of the students using them. For instance, the complexity of problems in the manipulatives rises with the understanding of the students, and hence encourages students to build further develop their skills and knowledge, without the need to seek new tools (Satsangi & Miller, 2017).

Virtual Laboratories Strategy

Virtual laboratories are digital (typically online) platforms that simulate the laboratory environment in the real world (Potkonjak, Gardner, Callaghan, Mattila, Guetl, Petrović, & Jovanović, 2016). It allows students to conduct experiments and explore scientific concepts without the need for physical lab equipment. This instructional strategy has gained traction in recent years with the advancements of technology and due to its potential to enhance learning outcomes.

Virtual laboratories are interactive and replicate the procedures, equipment, and outcomes of a physical laboratory. It leverages multimedia elements such as animations, simulations, and virtual reality (VR) to create an immersive learning environment. Through virtual laboratories, students can perform experiments, manipulate variables, and observe outcomes in real-time, all within a controlled digital setting. Their capabilities have been greatly expanded through time by advances in simulation software, graphics processing power, and computer power. High fidelity simulations, realistic graphics, and interactive features that closely resemble actual laboratory experiences are now available in modern virtual labs (Altalbe, 2018).

Virtual laboratories encompasses all the benefits associated with traditional laboratory instruction and is also associated with increased accessibility and flexibly as it is not limited by geographical or timing issues, with students able to access such laboratories at anytime from anywhere (Manuel et al., 2019).They are also cost-effective in the long term as while traditional physical labs require specialised tools, supplies and designated areas, and this can be costly to build, operate and maintain (Irwansyah, Slamet, & Ramdhani, 2018), virtual labs eliminate or reduces these costs.

Virtual laboratories are also notable for their safety. Virtual labs provide a useful alternative for lab work that might involve hazardous chemicals and apparatus, high voltages, and fragile equipment, this enabling the conducting of experiments without any of the associated risks.

The interactive and immersive nature of virtual labs can increase student engagement and motivation, even more than physical laboratories. Multimedia elements and gamification techniques make learning more enjoyable and effective. Virtual laboratories can also accommodate a large number of students simultaneously, making them ideal for large classes or institutions with limited physical lab space. Furthermore, virtual laboratories offer immediate feedback, helping students understand their mistakes and learn more effectively.

Conclusion

Innovation in instructional strategies is essential for transforming science education into a dynamic, engaging, and effective experience for learners. This article has highlighted some useful innovative instructional strategies that can be applied to teaching science ranging from the non-digital strategies like concrete representational abstract to digital based strategies like flipped classroom strategy. These strategies have the potential to revolutionise science teaching and learning process beyond what traditional classroom instructional strategies can provide.

Recommendations

The following recommendations were made;

i) Teachers should use innovative instructional strategies in the teaching and learning of science.
ii) Government should provide digital tools in schools for innovative teaching and learning of science.
iii) Government should train both the teachers and the learners in the use of digital tools for innovative teaching and learning of science.

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