Promoting constructivism as a pedagogy of learning among secondary science trainee teachers.

Abstract

Research shows that most science teachers do not practise constructivism, and this may pose a pedagogical challenge, especially for science trainee teachers (pre-service teachers). Teacher educators, therefore, should design a curriculum to support science trainee teachers in understanding what constitutes constructivism and how to implement it in their classrooms. This article draws upon two successful constructivist teaching strategies that can help science trainee teachers to promote learning in their classrooms. The strategies are not limited to science trainee teachers but apply to a broader range of disciplines in teacher education as the pedagogy is transferrable.

Introduction

Constructivism plays a key role in classroom assessment practices and students' learning. The Education Endowment Foundation (EEF, 2018), in its guidance on improving secondary science education, encourages teachers to build on the ideas that students bring to lessons, promote self-regulation, and model and use structured feedback to support students' thinking. These are embodied in constructivist learning and should be promoted in the science classroom. Constructivism has various lenses as portrayed by Piaget, Vygotsky, Bruner and Ausubel (See Niaz, 2008; Taber, 2010). The common forms of constructivism practiced in classrooms focus on Piaget and Vygotsky. Piaget's cognitive constructivism involves students creating knowledge in stages of cognitive abilities (Taber, 2016), while socio-cultural constructivism by Vygotsky allows students to create knowledge when working with others, a form of social interaction.

Teachers and students can benefit from interactions involving both forms of constructivism, but teachers should promote these forms of learning in their classrooms. However, research shows that most science teachers do not practice constructivism in their classrooms (Savasci & Berlin, 2012; Chen et al., 2022) due to a lack of pedagogical knowledge and a 'consensual understanding around what being a constructivist in science education entails' (Taber, 2016, p. 3). Creating awareness of the role of constructivism and engaging science trainee teachers in this form of learning will help them to understand the process, and plan and implement it in their classrooms. Therefore, when teachers and educators understand constructivist learning theory, it will enable them to recognise the experiences that students bring into the classrooms and how their backgrounds and previous knowledge can impact their learning. Teacher educators can help science trainee teachers by incorporating constructivism as a module in the initial teacher education curriculum and guiding them on how to design learning activities to support students' learning.

As a teacher educator supporting both science trainee teachers and experienced teachers, I have realised a lack of or inconsistencies on the part of experienced teachers in adopting constructivism as a pedagogy. Even when constructivist practice is carried out, it may be restricted to a few teachers (Savasci & Berlin, 2012; Mansour, 2013) due to a lack of pedagogical knowledge to implement it in their classrooms. Therefore, there is a dire need to promote constructivism as a pedagogy of learning among science trainee teachers (Allen & Bickhard, 2011; Taber, 2016) to help them become familiar with this type of practice and develop their classroom assessments as they become more experienced teachers. A consensus, therefore, may focus on supporting science trainee teachers' understanding of how children learn in science. This can be achieved by critically engaging with ideas about the nature of science (NoS), their alternative conceptions and communication in science.

Therefore, this article aims to support secondary science trainee teachers in planning and implementing constructivism in their classrooms by focusing on two effective and successful strategies. The strategies can also apply to a broader range of disciplines in teacher education.

Structure and perceptions of constructivism

Hartle, Baviskar and Smith (2012) suggest forms of constructivism as cognitive, personal and social. Niaz (2008, p. 407) asserts that constructivism is a *'heterogeneous movement which has many variants such as contextual, dialectical, empirical, Piagetian, pragmatic, radical, social and trivial'.* In contrast, Glasersfeld (1990) coined the term radical constructivism by taking a neutral standpoint that this paradigm contributes to the learning of students rather than opposing its role. He argues that radical constructivism assumes that the "*cognising activity is instrumental and does not concern anything but the experiential world of the knower'* (p. 2). In essence, the knower's experience is crucial in any cognitive activity by segmenting various aspects of experience to form viable abstract concepts leading to a relatively stable experiential reality. However, it can be argued that despite the knower being the subject of knowledge creation, there is a need for external sources of cognition to complement the experience of the knower and that is why radical constructivism, in some instances, can be seen to contradict constructivist practices. These various notions of constructivism can create confusion for practitioners who intend to adopt it in their classrooms. Taber (2010; 2016) and Hartle et al. (2012) contend that confusion may arise when describing different terms associated with constructivism. In the same way, Allen and Bickhard (2011) posit that passive and active ontologies are constraints on the conceptual possibilities for the different forms of constructivism. Nonetheless, knowledge creation can be considered a common theme among the different forms of constructivism, and science trainee teachers may need support in implementing this pedagogy in their classrooms to promote the learning of students.

Mansour (2013) postulates that just a few teachers' pedagogical beliefs align with constructivist philosophy while most do not. Experienced science teachers may have varying views about constructivism due to a lack of pedagogical knowledge which could hinder them from planning and implementing it in their classrooms. Savasci and Berlin (2012) echo this problem of pedagogy and assert that classroom observations show that three out of four science teachers do not practice constructivism in their classrooms despite the benefits to students' learning. Thus, we can infer that when the relevant support and strategies are in place, constructivism can enhance teachers' pedagogy and students' learning.

Constructivism encourages student-centred learning, and promotes responsible learners and metacognition (Hartle et al., 2012). Put succinctly by Niaz (2008), constructivism promotes learning as a social and dynamic process in which the learner constructs its significance. In contradistinction, Allen and Bickhard (2011) conclude that an emergent constructivist approach to learning is required to promote active ontologies, given that interaction from such an approach could develop cognition among learners. Therefore, it becomes relevant to highlight the benefits of this learning theory in promoting students' learning and deconstructing varying perspectives to help science trainee teachers to understand and implement it in their classrooms. Nayir, Yildirim and Kostur (2009) assert that trainees' views about constructivist teachers are that they should be aware of students' needs and interests, social, emotional, socio-economical differences and respond by altering their lesson plans and pedagogy. In essence, adaptive teaching in terms of pedagogy becomes an issue to contend with, and science trainee teachers should be given the relevant support to help them navigate this hurdle and promote students' learning.

Another barrier to implementing constructivist teaching can be a lack of subject knowledge. Without a good knowledge of the subject matter, trainee teachers may find it difficult to make learning accessible to students. Teacher educators can help science trainee teachers overcome this barrier by including activities such as problem-solving, researching areas of poor subject knowledge and peer teaching. Developing trainee teachers' subject and pedagogical content knowledge will help them to plan and implement constructivism in their classrooms and promote students' learning and understanding of the nature of science (Niaz, 2008) and differentiated learning strategies that focus on how children learn and communicate in the classroom. The nature of science will help trainee teachers to appreciate the history and philosophical underpinnings of science and can create awareness of how science works and knowledge creation. Teachers must support students in understanding the nature of science as this can impact their learning and how they engage with the materials provided. Despite the benefits of constructivism to knowledge creation and learning, it may confuse the way new knowledge is created and the learning of old knowledge. Therefore, constructivism fails to recognise its limitations and may have been promoted as having an impact on learning in science more than it should have. However, the argument lies on the premise that constructivism may have a fundamental theoretical problem in teaching the content of science. The reason being that if knowledge cannot be imparted, and if it is a matter of personal construction, then how can children come to the knowledge of complex conceptual schemes if they are not supported.

Why promote constructivism in classrooms

Eliciting learners' ideas can be the starting point for learning school science. This resonates with the view that in a constructivist-based classroom, teachers find out what students already know and challenge them to think and express themselves to add to their existing knowledge. Constructivism as a pedagogy relies on science trainee teachers' ability to encourage and propagate students' ideas, at the same time creating opportunities for cultural and social capital expressions, as these can play a key role in supporting students' learning. Adopting a sociocultural approach to learning in a constructivist environment can develop and sustain a culture of inquiry to bridge the gap between science trainee teachers' everyday knowledge and that provided by the university. This may help them to understand scientific processes and develop inquiry learning among students. Constructivist theories focus attention on the mental models that a learner employs when responding to new information or new problems. For learning to take place, there may be opportunity to analyse and transform any new information. Therefore, transformations of incoming ideas can only be achieved in light of what the learner already knows and understands. Unless learners make their thinking explicit to others, and themselves, they cannot be aware of the need for conceptual modification.

Hartle et al. (2012, p. 32) suggest four criteria for identifying constructivism such as '*eliciting prior knowledge, creating cognitive dissonance, applying new knowledge with feedback and reflecting on learning'*. Fulfilling these criteria may involve adopting strategies to maximise learning and this can be achieved through promoting collaborative and self-directed learning, reiteration and self-evaluation. Therefore, engaging science trainee teachers in constructivist teaching will help them to gain the relevant knowledge and skills required to carry it out in their classrooms. The knowledge acquired in this process can be viewed as co-constructed and the knower should have agency and a voice in the process of knowing and the process of learning should be dialogic.

Strategies for implementing constructivism in classrooms.

The lack of consistency in planning and implementing constructivism (Savasci & Berlin, 2012) can hinder teachers in promoting learning among students. Therefore, creating opportunities for science trainee teachers to experience constructivist pedagogy following the strategies discussed below would help them to understand how to plan and implement them in their classrooms. I will explore two successful strategies that can promote constructivism in the classroom. These are not limited to science-specific subjects but apply to a broader range of disciplines in teacher education.

Strategy 1

The first approach involves teacher educators reviewing selected areas of subject matter in which science trainee teachers have conceptual problems by allowing them to complete a subject knowledge audit of the national curriculum areas that they are training to teach. This will allow science trainee teachers to indicate their strengths and areas for development and decide how to focus on priority topics. For example, topics may include theories of evolution and relativity, forces, addressing misconceptions in photosynthesis and other science areas. By eliciting science trainee teachers' ideas and challenging their existing notions through questioning and retrieval tasks, educators can identify misconceptions and devise strategies to help them succeed. The next step involves promoting constructivist learning where science trainee teachers are placed in groups and provided with problem-solving tasks requiring them to 'critique the teaching of a priority topic that they have identified' through researching the current state of knowledge about the topic using various means such as teaching resources, observing lessons and speaking to educators. The purpose of the group is to help them articulate their ideas, interpret and gain new experiences, knowledge and beliefs and promote confidence among the science trainee teachers before presenting outcomes to their peers. The educator encourages questions and feedback (written and oral) from them.

The feedback given to the trainees involves using a set of success criteria such as demonstrating secure subject knowledge, collaboration, analysing and addressing misconceptions and evaluating teaching practices. The criteria have specific tasks that the science trainee teachers must be able to achieve. For example, addressing misconceptions may have the following tasks: science trainee teachers can analyse two or more misconceptions from a chosen topic and draw upon evidence from literature and discuss how the misconceptions arise and ways to address them; critically evaluate the importance of identifying children's misconceptions and using them as part of the teaching and learning process, and using models and other teaching strategies. These tasks are then graded on a Likert scale ranging from 1-5, with 1 as insufficient evidence and 5 as excellent. Each science trainee teacher reviews feedback given to them and discusses areas for development to collaboratively support the learning of others. Carrying out this task leads to conceptual change in science trainee teachers' subject knowledge, promotes constructivist learning and makes learning accessible to them. This resonates with the views that good subject knowledge and the knowledge of students' misconceptions can enhance students' performance and help them to overcome any barrier to their learning.

At some point during their studies, the science trainee teachers will go on school experience (practicum), where they will be required to teach secondary school science. The knowledge and skills gained from engaging in this activity while in the university will help them to implement similar pedagogy in their classrooms to promote learning. Therefore, for the benefit of science trainee teachers reading this article, I have adapted this strategy in the next paragraph to help them implement similar pedagogy in a secondary school science lesson.

At the secondary school level, science trainee teachers may start their lessons by using retrieval tasks such as questions to help students recall and apply knowledge. This will help to identify misconceptions and gaps in students' knowledge and to structure the content to meet their needs. The students can be assigned various topics in the curriculum and work in their groups to find information. Using structured group activities with students assigned various roles will enable them to research information from different sources such as textbooks, the internet, practical work and articles to promote collaborative learning. The science trainee teachers can use the think-pair-share strategy to allow the students to discuss what they have found in their groups before presenting it to others. A set of success criteria such as communication, subject knowledge content and teamwork can be used to score students' performances on the tasks. During presentations, students will be given opportunities to ask questions and to use the pose-pause-bounce-pounce strategy to tease out further information from their peers. Using the strategy allows students to pose questions, pause for others to think, bounce responses around the classroom and pounce by responding to or adding to others' responses. Where the students cannot respond to certain questions, the teacher can close gaps in their knowledge.

Strategy 2

The second approach to implementing constructivism focuses on problem-solving activity and the strategy features a sequence of learning based on the 5E instructional model for constructivist learning such as '*engagement, exploration, explanation, elaboration and evaluation'* (Bybee & Landes, 1990, p. 96). To engage science trainee teachers in this sequence of learning, they are placed in groups of four and provided with various problem-solving activities from selected topics. The groups are carefully assigned by the educator, based on their learning needs, to promote active learning through creating opportunities for inclusion, peer support and peer assessments.

In the engagement phase, science trainee teachers are provided with a problem-solving task such as: *'James collected samples of sugar, salt and sand in three different beakers in the lab. He tripped while moving these to his table during practical and the beakers broke. He now has a mixture of broken glass, sugar, salt and sand'*. What can he do to retrieve the individual samples? This problem is centred on the chemistry topic: 'elements, compounds and mixtures', taught at secondary schools in England. The engagement phase initiates the learning task between the past and present experiences of the science trainee teachers and focuses their thinking on the learning outcomes (Bybee & Landes, 1990). Anecdotal evidence has shown that science trainee teachers have misconceptions about the topic of elements, compounds and mixtures. Therefore, the educator can facilitate learning by checking their prior knowledge through questioning. This helps them to review what they know about the topic or what they would like to explore and identifying their misconceptions sets the scene for the next phase.

The exploration phase promotes inquiry experience among science trainee teachers as they research various materials to help them understand the context of the problem-solving task that is described in the engagement phase earlier. The inquiry experience can promote self-directed learning and the opportunity for them to apply process skills such as observing, questioning, investigating, testing predictions, hypothesising and sharing ideas with their peers. The experience of working with science trainee teachers shows that the exploration phase is crucial to the progress that they will make in the subsequent phases. Therefore, the CREAM (creative, reflective, effective, active and motivated) strategy for learning (Cottrell, 2013) can be used to support them. The CREAM strategy allows science trainee teachers to engage fully with the problems by promoting creativity, critical thinking, evaluation, self-regulatory learning and problem-solving. This enhances their ability to act on feedback from educators and peers. To achieve this, the trainee teachers are allowed to work in groups of four to develop a plan to solve the problem by researching the properties of the samples provided, their solubility in various chemicals and solutions, plan an investigation and decide the strategies to separate the mixtures as well as justify these strategies.

The creativity aspect enables science trainee teachers to develop ideas about the topic from the research they carried out and their pre-existing knowledge. It can help them to create concept cartoons with speech bubbles accompanied by evidence statements for or against the concepts they are exploring. Developing the concept cartoon promotes the link to real-life situations as science trainee teachers can relate to other peoples' ideas, encourage active learning and enable them to achieve the learning outcomes. A strong pedagogical element of using the CREAM framework is that it promotes inclusion among science trainee teachers, confidence, and co-construction of knowledge.

The explanation phase allows science trainee teachers to communicate what they have learned by presenting and sharing outcomes with other groups. For example, the concept cartoon created from the last activity may be presented to their peers who are required to decide which evidence they agree with and justify this. However, if they disagree with a piece of evidence, they are required to provide their own. The activity helps to model the idea of evaluating relevant evidence, promoting critical thinking and self-regulation. The educator encourages questions and feedback among the trainee teachers and identifies misconceptions. Rather than responding to their questions, educators may redirect the questions through a pose-pause-bounce-pounce strategy to engage them in meaningful discussions. The educator identifies areas that support understanding, allow articulation of concepts and advance learning. Various strategies can be useful in the explanation phase to support learning such as debate, argumentation, practical work and modelling.

The elaboration phase helps science trainee teachers to apply their knowledge in other contexts and link it to real-life situations or the world around them. They may use the skills gained to improve products or ideas and support their peers. The use of models, analogies and practical work can also be useful in this phase. The educator can provide the science trainee teachers with samples of substances used in the problem-solving (see the engagement phase) and allow them to carry out practical work to challenge and extend their conceptual understanding. Subsequently, should be able to share experiences that they may have developed from the tasks to enhance a deeper understanding and develop relevant skills such as investigation. In addition, it helps the science trainee teachers to decide upon the correct procedures for separating mixtures of the various substances and to understand how the knowledge of the properties of substances can be useful, and this would enable them to confirm the evidence has been provided earlier or disagree with it.

The evaluation phase helps the science trainee teachers and educators to know what learning has taken place. The educator can use questions to check that they can apply what they have learned and to know if they have modified their thinking. In the same way, science trainee teachers can create questions to ask their peers.

Engaging science trainee teachers in the 5E instructional model for constructivist learning facilitates cognitive activity and conceptual change by allowing them to find solutions to problems. Taking part in this constructivist learning process enables science trainee teachers to develop the necessary knowledge and skills to plan and implement constructivist teaching strategies in their classrooms.

Conclusion

Adopting constructivist teaching strategies can promote learning and therefore science trainee teachers should be engaged in this type of pedagogy to understand the processes involved and how best to implement them in their classrooms. Both strategies discussed can apply to the secondary school setting and can be adapted to suit the needs of the students. Constructivism is not a new concept, however, the lack of pedagogical knowledge of teachers may prevent them from practising it and this can affect students' learning. That is why this article seeks to promote this pedagogy among science trainee teachers to support them in the early stages of their careers to develop the knowledge and skills required to implement it. The teacher educators are responsible for providing this learning experience for science trainee teachers so that they can realise the benefits of constructivist teaching.

References

Allen, J. W. P., & Bickhard, M. H. (2011) 'Emergent constructivism', *Child Development Perspectives*, *5*(3), 164–165.

Bybee, R. & Landes, N. M. (1990) 'Science for life and living: An elementary school science program from Biological Sciences Improvement Study', (BSCS) *The American Biology Teacher, 52*(2), 92-98.

Chen, P. H., Hong, J. C., Ye, J. H. & Ho, Y. J. (2022) The Role of Teachers' Constructivist Beliefs in Classroom Observations: A Social Cognitive Theory Perspective. *Front. Psychol*. 13:904181. doi: 10.3389/fpsyg.2022.904181

Cottrell, S. (2013) *The study skills handbook* (4th edn.). Basingstoke: Palgrave Macmillan.

Education Endowment Foundation, EEF (2018). *Improving secondary science. Guidance report.* Available at: https://educationendowmentfoundation.org.uk/public/files/Publications/Science/EEF_improving_secondary_science.pdf Accessed 27.7.20

Glasersfeld, E. V. (1996). Aspects of radical constructivism and its educational recommendations. In L. P. Steffe, P. Nesher, P. Cobb, G. A. Goldin & B. Greer (Eds.), *Theories of mathematical learning* (pp. 307–314). Lawrence Erlbaum. Available at: http://www.vonglasersfeld.com/185

Hartle, R. T., Baviska, S. and Smith, R. (2012) 'A field guide to constructivism in the college science classroom: Four essential criteria and a guide to their usage', *Bioscene, 38*(2), 31-35.

Mansour, N. (2013) 'Consistencies and inconsistencies between science teachers' beliefs and Practices', *International Journal of Science Education, 35*(7) 1230-1275.

Nayir, O. Y., Yildrin, B. & Kostur, H. (2009). Pre-service teachers' opinions about Constructivism. Paper presented at the World Conference on Educational Sciences 2009. *Procedia Social and Behavioral Sciences* 1, 848–851.

Niaz, M. (2008) 'Whither constructivism? - A chemistry teachers' perspective', *Teaching and Teacher Education* 24, 400–416.

Savasci, F. & Berlin, D. (2012) ‘Science teacher beliefs and classroom practice related to constructivism in different school settings’, *Journal of Science Teacher Edu*cation *23* (1) 65-86.

Taber, K. S. (2010) ‘Paying lip-service to research? The adoption of a constructivist perspective to inform science teaching in the English curriculum context’, *The Curriculum Journal, 21* (1) 25–45.

Taber, K. S. (2016). Constructivism in Education: interpretations and criticisms from science education. In E. Railean (Ed.), *Handbook of Applied Learning Theory and Design in Modern Education* (pp. 116-144). Hershey, Pennsylvania: IGI Global.