Exploring Teacher Efficacy in Integrating Robotics and Concept-Based Approach for Teaching Chemistry Using the Periodic Table

THABO MHLONGO (✉ t.man907@hotmail.com)
Tshwane university of technology  https://orcid.org/0000-0002-9814-5691

Research Article

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Abstract

This study investigates the efficacy of integrating robotics and a concept-based approach in teaching chemistry, with a focus on the periodic table. Utilizing Bandura's social-cognitive theory and situational efficacy, a multiple-case study design involves four purposefully selected chemistry teachers. Data, gathered through classroom observations and semi-structured interviews, highlights how teachers’ conceptions, beliefs, and characteristics shape their integration of robotics in chemistry education. Positive outcomes include heightened learner interest, improved understanding, and increased motivation. The study emphasizes the value of interdisciplinary learning, inquiry-based activities, and continuous professional development for successful integration. The findings provide insights for enhancing teaching efficacy and improving learning outcomes in chemistry education, guiding future research and professional development initiatives.

INTRODUCTION

The use of robotics in contemporary education has received a lot of attention recently, particularly in the teaching of sciences like chemistry. Robotics integration with concept-based approach in chemistry education is a cutting-edge strategy that can improve teacher efficacy and changed the way learners experience the classroom (Faseyitan & Stains, 2020; Han, Yang, & Niu, 2019). With the development of technology and the shift in learner learning patterns, there is an increasing demand for creative teaching strategies to enhance learning results (Barak & Doppelt, 2019; Hardesty, 2019). According to studies such as Cheon et al., 2014 and Wei et al., 2013, learners' motivation and engagement have increased when technology is used in the classroom. These are two important markers of good learning outcomes (Cheon et al., 2014 and Wei et al., 2013).

While there is a growing emphasis on the integration of robotics in contemporary education, a notable gap persists in our understanding of how the fusion of robotics with the concept-based approach impacts teaching chemistry, particularly using the periodic table. Despite the acknowledged potential of robotics to revolutionize the learning experience (Faseyitan & Stains, 2020; Han, Yang, & Niu, 2019), there is limited research exploring its specific applications within the realm of chemistry education. This study aims to fill this gap by investigating the efficacy of integrating robotics and the concept-based approach, shedding light on the nuanced dynamics that influence teacher practices and learner outcomes in the context of teaching chemistry with a focus on the periodic table.

Specifically, the study aims to explore how integrating robotics and concept based approach in chemistry affects teacher efficacy. According to Goddard et al. (2000), teacher efficacy is the degree of assurance and self-efficacy a teacher has in their capacity to lead lessons well and favourably impact learner learning outcomes. In accordance with the social-cognitive theory developed by Albert Bandura, teachers' efficacy beliefs have a major impact on how they conduct instruction, which in turn affects how well their learners learn (Bandura, 1997).
One of the crucial educational fields where robotics integration could be quite beneficial is chemistry, which necessitates a thorough comprehension of difficult topics (Chang et al., 2016). Robotics technology, including sensors and microcontrollers, can give immediate feedback on manipulations and lab experiments that improve comprehension of chemical ideas and aid in their reinforcement (Jed, A., Alsaad & Dagriri, 2020; Melendez & Devasirvatham, 2019). Learners can now imitate procedures that were previously unattainable in conventional classroom learning thanks to the incorporation of robotics.

This study investigates the effects of robotics integration with concept base approach on teacher effectiveness and learner learning outcome in chemistry. It does this by drawing on the theoretical frameworks of Bandura's social-cognitive theory and situational efficacy. The situational efficacy model focuses on how teachers' perceptions of their own efficacy shift in response to various learning environments (Bandura, 1997; Ashton & Webb, 1986). The situational setting in this study that influences teacher efficacy perceptions is the use of robotics technology into concept-based chemistry instruction.

In the realm of education, the term 'concept-based approach' refers to an instructional methodology that centers on fostering a deep understanding of overarching concepts and principles rather than rote memorization of isolated facts. In the context of this study, the concept-based approach in teaching chemistry entails an immersive pedagogical strategy where educators emphasize the interconnectedness of chemical concepts, encouraging students to explore the fundamental principles that govern the subject. This approach not only cultivates a holistic comprehension of the material but also aligns with the dynamic and interactive nature of contemporary educational practices.

As the landscape of education evolves with the integration of robotics, there arises a crucial need to delve into specific applications within the domain of chemistry education. While existing literature acknowledges the transformative potential of robotics (Faseyitan & Stains, 2020), a discernible gap exists in understanding how this transformative power can be harnessed effectively in teaching chemistry, particularly with a focus on the periodic table. In light of this gap, the central question guiding this investigation is: How do teachers perceive the integration of robotics and the concept-based approach in teaching science, and what factors influence their approach towards teaching chemistry using robotics? This research question is pivotal in unravelling the intricacies of leveraging robotics for enhanced chemistry education, providing valuable insights for educators, researchers, and policymakers alike.

**METHODS**

In this study, a qualitative approach was employed to explore the efficacy of teachers in teaching chemistry using the periodic table and robotics with a concept-based approach. Qualitative methods are particularly suitable for examining nuanced experiences and perceptions in educational settings (Denzin & Lincoln, 2018; Creswell, J. W., & Creswell, 2017).

**Research Design and Rationale**
An interpretative multiple-case study design was chosen to facilitate an in-depth exploration of the integration of robotics and the concept-based approach in diverse school contexts. This design allows for detailed insights into how teachers navigate the complexities of teaching chemistry with technology.

**Sampling Strategy**

The target population comprised grade 10 chemistry teachers in two selected schools. Purposive sampling was used to select participants with substantial experience in teaching chemistry, specifically those who had implemented the concept-based approach and robotics integration. The criteria for selection included a minimum number of years of teaching experience, expertise in the concept-based approach, and prior experience with robotics integration.

**Sample Size and Generalizability**

While the sample size is limited to four teachers (two from each school), this study prioritizes in-depth exploration over broad generalizations. The findings are context-specific, and the study acknowledges the inherent limitations in generalizability due to the small sample size.

**Data Collection**

Data was collected through comprehensive methods to gain a holistic understanding of teachers' efficacy. Classroom observations involved the researchers observing chemistry classes where teachers integrated robotics and the concept-based approach. Semi-structured interviews were conducted individually with participating teachers to explore their experiences, perceptions, and beliefs regarding the integration. These interviews provided an in-depth understanding of teachers' efficacy and insights into the impact on learners' outcomes.

**Data Analysis**

Thematic analysis, following procedures outlined by Nowell et al. (2017) and Guest et al. (2012), was employed. This involved identifying recurring themes, patterns, and connections within and across cases, ensuring rigor, reliability, and credibility of the analysis.

**Ethical Considerations**

Ethical considerations included obtaining informed consent from participants, ensuring confidentiality, and addressing any potential risks to participants. The study adhered to ethical guidelines in research involving human subjects.

**RESULTS AND DISCUSSION**

The study provides insightful perspectives into teachers' conceptions of integrating robotics with a concept-based approach in teaching chemistry. Analyses of various aspects, including concepts, meanings, beliefs, nature of science, teacher/learner characteristics, rationale for teaching, and preferred
teaching techniques, illuminate how teachers perceive and approach the integration of robotics and the concept-based approach in their instructional practices.

The findings contribute to a comprehensive understanding of robotics concepts within a concept-based chemistry teaching methodology. Varied perspectives among teachers underscore the need for educators to critically reflect on their practices, considering broader educational and societal implications. The diversity in teachers' viewpoints, as presented in Table 1, emphasizes the importance of tailored approaches to maximize engagement and learning outcomes.

The results underscore the significance of inquiry-based learning, multidisciplinary education, learner-centered methods, and problem-solving activities in enhancing learner motivation, engagement, and comprehension within the context of robotics education. These insights lay the foundation for further research and professional development initiatives aimed at refining the integration of robotics and concept-based teaching in science education.
Table 1
Teachers' conception of the use of robotics in chemistry.

<table>
<thead>
<tr>
<th>DESCRIPTIONS OF ASPECTS OF ANALYSIS</th>
<th>DESCRIPTION AND CHARACTERIZATION OF ASPECTS OF THE CONCEPTIONS OF THE ROBOTICS WITH CONCEPT-BASED TEACHING</th>
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<tbody>
<tr>
<td>MEANINGS</td>
<td>[APPENDIX A: OBS 108, OBS 113, OBS 116]</td>
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<tr>
<td>The meaning of using robotics in teaching technological concepts refers to the content that is to be taught about robots and their applications. It specifically targets the intended object of the teaching, which is what the teacher intends the learner to learn about robotics and its various aspects. (Hewson &amp; Hewson, 1989).</td>
<td>• T1 may see robotics as a means to accomplish specific tasks or applications, while T2 recognizes the transformative potential of robotics in various fields and industries.</td>
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<td>• T1 may prioritize practical applications of robotics without fully addressing the deeper meaning of robotics in teaching, such as fostering creativity, innovation, and real-world problem-solving. In contrast, T2 emphasizes the development of skills such as critical thinking, collaboration, and adaptability through robotics projects.</td>
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<tr>
<td></td>
<td>• T3 meaning of the use of robotics in teaching goes beyond completing specific tasks. They emphasize the deeper meanings of robotics, such as fostering creativity, innovation, and problem-solving skills. T3 aims to help learners understand the broader educational and societal implications of robotics.</td>
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<td></td>
<td>• T4: Similar to T3, T4 emphasizes the meaning of robotics in teaching beyond mere task completion. They believe that robotics can foster critical thinking and creativity, enabling learners to develop their own projects and solutions. T4 aims to create a learning environment where learners can explore the transformative potential of robotics.</td>
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<td>NATURE OF SCIENCE</td>
<td>[APPENDIX A: OBS 110, OBS 125, OBS 104]</td>
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<tr>
<td>The educational material focusing on robotics that the teacher aims for the learner to comprehend (hewson &amp; hewson, 1989).</td>
<td>・T1's teaching approach may be more teacher-centered, where they present predefined information about robotics without exploring the scientific principles behind it. In contrast, T2 emphasizes a more learner-centered approach, involving learners in the construction and application of robotics knowledge.</td>
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<td></td>
<td>・T3's teaching approach involves a more learner-centered approach, allowing learners to engage in the construction and application of robotics knowledge. They emphasize the integration of robotics concepts with other scientific principles, providing learners with a deeper understanding of the nature of science behind robotics.</td>
</tr>
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<td></td>
<td>・T4's inquiry-based approach encourages learners to investigate and discover robotics concepts through hands-on experiments. T4 promotes the understanding of the scientific principles and processes through which robotics operates, enabling learners to develop a broader understanding of the nature of science.</td>
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<tr>
<td>TEACHER/LEARNER CHARACTERISTICS</td>
<td>[APPENDIX A: OBS 110]</td>
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<tr>
<td>Factors that are probable to impact how and what an individual instructs when it comes to robotics. (hewson &amp; hewson, 1989).</td>
<td>・T1 characteristics influenced how and what was taught about chemistry using robotics.</td>
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<td></td>
<td>・T2 had technical knowledge and expertise in robotics and provided more effectiveness in integrating robotics into their teaching. Learners' prior experience and interest in robotics may also impact their engagement and motivation in the learning process.</td>
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<td></td>
<td>・T3, as a teacher, values interdisciplinary learning and collaboration. They create opportunities for learners to work together in groups and develop teamwork and communication skills. T3 recognizes the importance of prior experience and interest in robotics as learner characteristics that can impact engagement and motivation.</td>
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<td></td>
<td>・T4, as a teacher, values curiosity and critical thinking in learners. They foster a sense of inquiry and encourage learners to ask questions, analyze data, and draw conclusions. T4 believes that learner characteristics such as curiosity and willingness to experiment play a crucial role in the effectiveness of robotics teaching.</td>
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<tr>
<td>DESCRIPTIONS OF ASPECTS OF ANALYSIS</td>
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<tr>
<td>RATIONAL FOR TEACHING</td>
<td>[APPENDIX A: OBS 104]</td>
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| Justifications that an individual may provide for employing a specific instructional approach to teach the periodic table. (hewson & hewson, 1989). | • The reasons for using a particular teaching method or technique for teaching robotics may be influenced by the desired outcomes and goals of the teaching. T1 may prioritize practical applications and task completion, while T2 may prioritize the development of critical thinking, problem-solving, and creative skills through robotics projects.

• T3's rational for teaching robotics may be influenced by the desired outcomes of interdisciplinary learning, fostering creativity, and developing problem-solving skills. They believe that robotics can provide practical applications and real-world problem-solving experiences for learners.

• T4's rational for teaching robotics may be influenced by the desired outcomes of inquiry-based learning, fostering critical thinking, and promoting creativity. They believe that robotics can provide opportunities for learners to develop their own projects, think innovatively, and apply scientific principles in a practical context. |

<table>
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<th>PREFERRED TEACHING TECHNIQUE</th>
<th>[APPENDIX A: OBS 100, OBS 135, OBS 110]</th>
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</table>
| Approaches, methodologies, tactics, and exercises that the person would employ to effectively utilize robotics. | • T1 and T2 preferred teaching strategies, techniques, methods, and practices for teaching robotics may include hands-on experimentation, project-based learning, and incorporating robotics concepts with other science principles.

• T3 may prefer teaching techniques that involve hands-on experimentation, project-based learning, and integration of robotics with other subjects. They strive to create a collaborative learning environment where learners can actively explore and apply robotics concepts.

• T4 may prefer teaching techniques that involve inquiry-based learning, problem-solving tasks, and opportunities for learner-designed projects. They believe in providing learners with the freedom to investigate and discover robotics concepts themselves. |

Constructivism emphasizes that learners actively construct their knowledge and understanding through interaction with their environment (Jonassen, 1999). T1’s approach seems to align with a behaviourist perspective, where the teacher presents predefined information without exploring the scientific principles behind robotics. In contrast, T2, T3, and T4 embrace a constructivist approach, where learners are actively
engaged in constructing their knowledge and understanding of robotics through hands-on experimentation, project-based learning, and inquiry-based tasks.

T2’s emphasis on integrating robotics concepts with related topics aligns with the concept of meaningful learning. According to Ausubel’s meaningful learning theory, meaningful learning occurs when new information is connected to existing knowledge and incorporates cognitive processes such as organization and elaboration (Ausubel, 1963). By integrating robotics with chemistry using the periodic table (as a tool and content system), T2 provides learners with a meaningful learning experience by connecting robotics with chemistry concepts to their prior knowledge and fostering deeper understanding.

T3’s emphasis on interdisciplinary learning and collaboration aligns with the socio-cultural theory of learning. According to Vygotsky, learning is an inherently social and cultural process that occurs through interactions with others (Vygotsky, 1978). By integrating robotics with chemistry concepts and fostering collaboration, T3 creates an environment where learners can engage in peer-peer interactions, collaborate on projects, and collectively construct knowledge. This collaborative approach facilitates higher-level thinking and the co-construction of understanding, aligning with the socio-cultural theory (Rogoff, 1990; Palincsar & Brown, 1984).

T4’s inquiry-based approach aligns with the process of scientific inquiry and the theory of situated cognition. According to situated cognition, knowledge is situated within a specific context and is developed through authentic, real-world experiences (Brown et al., 1989). By engaging learners in hands-on experiments and problem-solving tasks, T4 provides opportunities for learners to actively participate in the scientific inquiry process, allowing them to develop a deeper understanding of scientific principles while applying them in practical contexts.

Furthermore, the characteristics and beliefs of the teachers can influence their instructional approaches. T1’s beliefs prioritize practical applications, possibly leading to a more teacher-centered approach. T2’s technical knowledge and expertise in robotics enable them to effectively integrate robotics into teaching. T3’s value for interdisciplinary learning and collaboration reflects their belief in the need to prepare learners for future careers. T4 values curiosity and critical thinking, which aligns with their belief in the importance of fostering creativity and innovation in learners.

These findings highlight the importance of considering different conceptions, beliefs, teaching techniques, and teacher and learner characteristics in the context of integrating robotics in chemistry education. The application of relevant theories such as constructivism, meaningful learning, socio-cultural theory, and situated cognition helps to understand the theoretical foundations and implications of each teacher’s approach.

The analysis reveals a spectrum of perspectives, approaches, and beliefs among teachers regarding robotics in education. There’s a notable diversity in how teachers conceptualize the role of robotics, ranging from practical applications to fostering creativity, critical thinking, and interdisciplinary connections. Varied teaching techniques and methodologies reflect the dynamic nature of integrating
robotics into education. Recognizing the individual characteristics of teachers and learners as influential factors highlights the need for tailored approaches to maximize engagement and learning outcomes. This analysis offers a nuanced understanding of the multifaceted landscape surrounding the integration of robotics with concept-based teaching, emphasizing the importance of pedagogical flexibility and learner-centric approaches.

By recognizing and understanding these different approaches, educators and policymakers can make informed decisions about how to effectively integrate robotics into the curriculum. It is important to consider the broader goals of robotics education, such as developing critical thinking skills, fostering creativity, preparing learners for future careers, and promoting interdisciplinary learning.

The interview responses further support and complement the findings. The findings from the interviews with T1 and T4 provide valuable insights into the integration of robotics and the concept-based approach in teaching chemistry concepts. Both teachers recognize the benefits of using robotics and the concept-based approach, such as increased learner interest, understanding, and motivation (see Table 2). The decision to incorporate interviews as an additional data source was driven by the researcher's aim to acquire a more thorough comprehension of teachers' viewpoints and methodologies regarding the integration of robotics into chemistry education. The selection of interviews was based on their capacity to facilitate open-ended inquiries and direct interactions, enabling the researcher to delve into subtleties, motivations, and experiences that may be inadequately captured by alternative data collection methods like surveys or observations.

The choice to involve two teachers, as opposed to the entire pool of four, was strategic and aimed at ensuring a diverse representation of perspectives while also managing the overall scope of the study. The insights gained from these two teachers were deemed valuable, given their distinctive approaches, beliefs, or experiences related to the amalgamation of robotics and concept-based teaching. While interviewing all four teachers might have been resource-intensive, opting for a representative sample was still considered conducive to obtaining meaningful and substantial data.

In qualitative research, the emphasis often leans towards depth rather than breadth, with the goal of attaining an exhaustive understanding of the phenomenon under examination (Patton, 2015; Creswell, 2013). By concentrating on these two teachers in a comprehensive manner, the researcher was able to meticulously explore their experiences, resulting in detailed insights that significantly contribute to the overarching findings of the study. Furthermore, practical constraints, such as limitations in time and resources, played a role in steering the decision to conduct interviews with a subset of teachers.
<table>
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<tr>
<th>INTERVIEW QUESTIONS</th>
<th>T1 RESPONSES</th>
<th>T4 RESPONSES</th>
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<tbody>
<tr>
<td>1. What is your background in teaching chemistry, and how long have you been using a concept-based approach in teaching this subject?</td>
<td>I started knowing chemistry at high school as a subject combined with physics. I now teach it and have two years of using the method of concept-based approach.</td>
<td>Teaching chemistry requires practical activities such as experiments, whereby the concept is simultaneously factually proven with the latter and colourful displays. I have used a concept-based approach since from novice stages in the pedagogical field.</td>
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<tr>
<td>2. How do you integrate robotics in teaching chemistry concepts, particularly focusing on the periodic table?</td>
<td>Robotics are flexible, I can do it by using its flexibility although not relying on them totally but making sure of their flexibility to assist my learners understand the periodic table other than cram-work.</td>
<td>Shifting to the periodic table (concept), robotics is integrated where the chemistry lesson needs to be more vivid. I use robotics in instances where I have to show how bonds are formed.</td>
</tr>
<tr>
<td>3. What level of efficacy do you possess in using robotics and concept-based approach in teaching chemistry?</td>
<td>So far I can say that I am 50% efficient, the reason being that I still need some more workshop as my work experience is not that enough.</td>
<td>I have sufficient level in terms of comprehension preferably concept-based approach rather than using robotics in teaching chemistry. I still have a gap to bridge in terms of robotics.</td>
</tr>
<tr>
<td>4. What benefits have you witnessed so far by using robotics and concept-based approach in teaching chemistry, particularly focusing on the periodic table?</td>
<td>My learners are more interested, they show more interest when interacting with robotics and concept-based approach. They show more understanding of the periodic table than when we do the traditional teaching and learning.</td>
<td>Concept-based approaches and using robotics help simplify a lesson and makes teaching easier. It caters for all learners at once, making the lesson practical also helps learners to quickly and easily grasp the core ideas.</td>
</tr>
<tr>
<td>5. To what extent do you think the use of technology, such as robotics, has improved your ability to motivate learners and enhance their understanding of chemistry concepts?</td>
<td>The use of technology has made me feel more confident that when I used to rely on my own knowledge in education. It has powerfully improved my ability to motivate learners and understand chemistry.</td>
<td>Using robotics helps intrigue and elicit learners interest, have their full attention and therefore they are more likely to learn effectively.</td>
</tr>
<tr>
<td>6. How do you plan to continue integrating robotics in teaching concepts and improving your efficacy as a teacher in the future?</td>
<td>I will make robotics awareness at school to raise funds to build the lab for robotics so that learners will have enough space and time to be taught in a technical style. I will also help other teachers to integrate robotics in teaching their subject because team work is the best.</td>
<td>I plan to continue integrate robotics and even improve on the approach. I plan on making the major of the lesson more robotics and colourful so as for the reality of the concept.</td>
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FINDINGS
INTERVIEW QUESTIONS | T1 RESPONSES | T4 RESPONSES
--- | --- | ---
**Teaching Background and Experience**
- T1 has been teaching chemistry and using the concept-based approach for two years.
- T4 has experience in teaching chemistry and using the concept-based approach since their early stages in the pedagogical field.

**Integration of Robotics in Teaching Chemistry**
- Both T1 and T4 emphasize the flexibility of robotics in teaching chemistry concepts, particularly in making the periodic table more vivid and showing how bonds are formed.

**Efficacy in Using Robotics and Concept-Based Approach**
- T1 considers themselves 50% efficient in using robotics and the concept-based approach in teaching chemistry, acknowledging the need for more workshops and experience.
- T4 expresses a sufficient level of efficacy in comprehension, particularly with the concept-based approach, while acknowledging the need to bridge the gap in terms of robotics.

**Benefits of Using Robotics and Concept-Based Approach**
- T1 highlights increased learner interest and understanding of the periodic table compared to traditional teaching methods.
- T4 mentions that the concept-based approach combined with robotics simplifies lessons, caters to all learners, and helps learners grasp core ideas quickly and easily.

**Enhancement of Learner Motivation and Understanding**
- T1 feels more confident in their ability to motivate learners and enhance their understanding of chemistry concepts through the use of technology, particularly robotics.
- T4 agrees, stating that using robotics helps intrigue and elicit learners' interest, leading to more effective learning.

**Future Integration of Robotics and Professional Growth**
- T1 plans to raise awareness about robotics at their school and build a robotics lab to provide learners with a dedicated space for technical-style teaching. They also express a willingness to help other teachers integrate robotics into their subjects.
- T4 intends to continue integrating robotics and improving on the approach, aiming for more robotics and colorful elements to enhance the reality of concepts.

Overall both T1 and T4 recognize the benefits of integrating robotics and the concept-based approach in teaching chemistry, including increased learner engagement, understanding, and motivation. They also demonstrate a commitment to ongoing professional growth and finding ways to further enhance their teaching practices.

T1 mentioned that the flexibility of robotics assists in making the periodic table more vivid and helps learners understand the concept better. This aligns with the findings that robotics can enhance the visual representation of chemical elements and their interactions, providing a more tangible and engaging learning experience (Chai et al., 2013). T4 also highlighted the use of robotics in demonstrating how
bonds are formed, which reinforces the idea that robotics can support hands-on experimentation and practical understanding of chemistry concepts (Shadle et al., 2019).

T1 acknowledged that they still have room for improvement in terms of their proficiency with robotics and the concept-based approach. This reflects the importance of continuous professional development and seeking opportunities to enhance teaching skills and knowledge. T4, on the other hand, expressed confidence in their comprehension of the concept-based approach but recognized the need to bridge the gap in terms of robotics. This highlights the significance of ongoing learning and growth, particularly in regards to integrating technology into instructional practices.

Both T1 and T4 reported positive outcomes from using robotics and the concept-based approach. T1 noted increased learner interest and understanding of the periodic table, emphasizing the contrast with traditional teaching methods. This aligns with previous research that has shown the effectiveness of robotics in enhancing learner motivation, engagement, and conceptual understanding (Wirth et al., 2018). T4 emphasized that the concept-based approach combined with robotics simplifies lessons, caters to all learners, and facilitates the grasping of core ideas. This highlights the value of incorporating hands-on activities and inquiry-based learning to promote deeper understanding and critical thinking (McDonald et al., 2018).

Both teachers acknowledged the role of technology, particularly robotics, in enhancing their ability to motivate learners and improve their understanding of chemistry concepts. This finding aligns with previous research that has highlighted the positive impact of technology on learner motivation, engagement, and learning outcomes (Shin et al., 2019). The use of robotics can create a dynamic and interactive learning environment that captivates learners' attention and encourages active participation, ultimately leading to better understanding and retention of concepts.

In terms of future integration and professional growth, T1 outlined plans to raise awareness about robotics at their school, establish a dedicated robotics lab, and support other teachers in integrating robotics into their subjects. This demonstrates a commitment to promoting interdisciplinary learning and collaboration within the school community. T4 expressed intentions to further integrate robotics into their lessons, making them more colorful and realistic. This indicates a desire to continually enhance the teaching and learning experience, promoting creativity and innovative thinking.

The interviews with T1 and T4 provide valuable insights into the integration of robotics and the concept-based approach in teaching chemistry. Both teachers recognize the benefits of using robotics and the concept-based approach, including increased learner interest, understanding, and motivation. They also demonstrate a commitment to ongoing professional growth and finding ways to further enhance their teaching practices.

CONCLUSION
This study aimed to explore the efficacy of teachers in teaching chemistry using the periodic table and the use of robotics with a concept-based approach. The study findings revealed that the integration of robotics and the concept-based approach in teaching chemistry could enhance teacher efficacy, motivation, and stimulate learners' interest. The qualitative research design involved multiple-case studies, observations, and interviews with chemistry teachers. The analysis of data collected revealed key insights into conceptions, beliefs, teaching techniques, and teacher and learner characteristics in the context of integrating robotics in chemistry education. Furthermore, the findings suggest that theories such as constructivism, socio-cultural theory, meaningful learning, and situated cognition could provide a theoretical foundation for the integration of robotics in teaching chemistry.

The results of the study provide valuable insights into the impact of robotics and the concept-based approach on teacher efficacy and learner learning outcomes in the context of chemistry education. The findings widen the scope of research on the integration of technology into teaching and learning and highlight the broader goals of robotics education, such as enhancing critical thinking skills and fostering creativity. The study recommends ongoing professional development initiatives and interdisciplinary learning opportunities to prepare learners for future careers and equip them with relevant skills. This study's insights can serve as a foundation for further research and professional development initiatives aimed at enhancing the integration of robotics and concept-based teaching in science education.

REFERENCES


**Supplementary Files**

This is a list of supplementary files associated with this preprint. Click to download.

- APPENDIXA.docx