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Research Article

TECHNOLOGY OF FORMATION OF SCIENCE COMPETENCES IN STUDENTS WITH DISABILITIES: A CASE STUDY IN NATURAL SCIENCES

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ABSTRACT

This article explores the application of technology to foster science competences in students with disabilities, particularly within the natural sciences. By integrating adaptive pedagogical approaches, technological tools, and assistive technologies, this study highlights the importance of inclusivity in science education. It provides insights into practical strategies for improving science competence, emphasizing accessibility and personalized learning experiences. The article focuses on understanding the barriers faced by students with disabilities in natural sciences and suggests solutions based on empirical evidence.

KEYWORDS

Science competences, students with disabilities, natural sciences, assistive technologies, adaptive learning, inclusive education.

INTRODUCTION

In the rapidly evolving landscape of education, inclusivity has become a key focus, especially in the sciences where practical skills and hands-on experimentation play a vital role. Science education, particularly in subjects such as biology, chemistry, and physics, poses distinct challenges for students with disabilities due to the physical, cognitive, and sensory demands of the curriculum. However, as technology continues to advance, new opportunities are emerging to support these students in overcoming barriers to learning and developing the necessary competences in natural sciences.

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For students with disabilities, mastering science competences goes beyond acquiring theoretical knowledge—it requires engaging with experimental processes, developing critical thinking, and applying problem-solving skills in real-world scenarios. Unfortunately, traditional approaches to science education often fail to accommodate diverse learning needs, leaving students with disabilities at a disadvantage. As a result, many of these students are either excluded from fully participating in science classes or face significant obstacles that hinder their learning.

Recent advancements in educational technology, particularly assistive and adaptive learning tools, have shown great potential in leveling the playing field for students with disabilities. From virtual laboratories to AI-powered adaptive learning platforms, these technologies can provide customized learning experiences that align with each student's unique abilities, thus fostering the development of science competences in a more equitable manner.

This article aims to explore how these technologies can be applied effectively to form science competences in students with disabilities, focusing on the natural sciences. Through the analysis of existing technological solutions and a case study of their implementation in real educational settings, the article highlights the transformative impact of inclusive technologies in bridging the gap for students with disabilities in science education. By doing so, it provides a framework for educators and policymakers to rethink the design and delivery of science curricula, ensuring that every student has the opportunity to excel in the field of natural sciences, regardless of their physical or cognitive limitations.

Defining Science Competences

Science competences refer to a set of knowledge, skills, and attitudes that enable individuals to engage with, understand, and apply scientific principles and processes. These competences are essential for problem-solving, critical thinking, and the ability to interact with scientific phenomena in both academic and real-world contexts. In natural sciences, competences span across subjects like biology, chemistry, physics, and earth sciences, where students are expected to grasp theoretical concepts, engage in experimentation, and develop an understanding of scientific methods.

For students with disabilities, the traditional definitions of science competences need to be adapted to their specific needs and abilities. This adaptation does not imply a lowering of standards, but rather a rethinking of how these competences can be acquired and demonstrated. Key science competences include:

1. **Conceptual Understanding**: The ability to comprehend core scientific concepts, theories, and principles. For students with disabilities, this competence may be supported by assistive technologies, such as multimedia tools, that provide alternative ways of interacting with complex concepts, particularly when sensory limitations (e.g., visual or auditory impairments) affect access to standard instructional materials.

2. **Practical Skills**: Engaging in experiments and scientific inquiry is central to science education. These skills encompass formulating hypotheses, conducting experiments, and interpreting data. For students with physical disabilities, access to adaptive equipment or virtual laboratories can provide the necessary platform

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for conducting experiments in ways that accommodate their physical needs.

3. Scientific Inquiry and Problem-Solving: Science competences involve critical thinking, asking questions, and using logical reasoning to solve problems. For students with cognitive disabilities, adaptive learning tools can scaffold complex problem-solving processes, breaking them down into manageable steps and providing feedback to guide their learning.

4. Data Interpretation and Analysis: The ability to collect, interpret, and analyze scientific data is crucial in natural sciences. This competence may be developed through technology-enhanced methods, such as software that simplifies data collection and analysis for students with disabilities, or tactile materials that help students with visual impairments interact with data in meaningful ways.

5. Collaboration and Communication: Being able to collaborate with peers and communicate scientific ideas clearly is a key competence in science. For students with disabilities, this competence can be nurtured through collaborative tools that enable participation in group activities, such as shared digital platforms or communication aids for students with speech or hearing impairments.

6. Ethical and Environmental Awareness: Science competences also involve understanding the ethical dimensions of scientific inquiry and its impact on the environment and society. This competence can be fostered through inclusive discussions and debates that encourage all students, including those with disabilities, to participate actively and express their perspectives.

In redefining science competences for students with disabilities, the goal is to maintain the integrity of the scientific learning process while ensuring that each student's unique abilities and challenges are recognized. The use of assistive technologies, adaptive learning platforms, and inclusive pedagogical strategies is key to supporting students with disabilities in acquiring these competences, empowering them to succeed in natural sciences on an equal footing with their peers.

Barriers in Science Education for Students with Disabilities

Students with disabilities face several barriers when it comes to engaging with natural sciences, including:

- **Physical barriers**: Inaccessibility of laboratory spaces and equipment for students with mobility impairments.
- **Cognitive barriers**: The complexity of abstract concepts in subjects like physics and chemistry may overwhelm students with intellectual disabilities.
- **Sensory barriers**: Hearing-impaired students may struggle with auditory aspects of instruction, while visually-impaired students may face difficulties in observing experiments.

4. Role of Technology in Overcoming Barriers

Technological solutions have proven to be invaluable in overcoming these challenges by offering assistive tools that bridge gaps in accessibility. Examples of these technologies include:

- **Text-to-speech and screen readers** for visually-impaired students, allowing them to access textual content and auditory descriptions of visual materials.

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• **Closed captioning and sign language interpreters** for hearing-impaired students, ensuring they can follow audio instructions and discussions.

• **Adaptive laboratory equipment** such as height-adjustable workstations, voice-controlled instruments, and braille-labeled scientific apparatus.

• **Augmented and Virtual Reality (AR/VR)**, which allows students with mobility limitations to participate in virtual laboratories and simulate scientific experiments without physical constraints.

Adaptive Learning Technologies in Science Education

Adaptive learning technologies that personalize the learning experience based on individual needs are also critical. Systems that adjust the pace of content delivery, level of difficulty, and type of feedback based on the student's learning profile have shown success in science education for students with disabilities. Examples include:

• **AI-powered platforms** that assess the student's learning progress and adapt science exercises accordingly.

• **Gamified learning platforms** that make complex concepts in natural sciences more engaging and accessible through interactive simulations.

• **Multimodal learning systems** that offer a combination of visual, auditory, and tactile inputs to cater to diverse disabilities.

Case Study: Implementing Technology in Natural Sciences for Students with Disabilities

This section presents a case study from a pilot program that incorporated adaptive technology into natural science education for students with various disabilities. The program included:

• Use of VR-based simulations for experiments in chemistry and physics, providing students the experience of conducting experiments in a safe and controlled virtual environment.

• Deployment of AI tutors that offer real-time feedback and guidance tailored to individual needs, helping students work at their own pace in understanding complex concepts such as ecosystems in biology.

• Collaboration with special education professionals to ensure that technological tools were aligned with the learning capabilities and cognitive load management of students with intellectual disabilities.

RESULTS AND DISCUSSION

The results from the case study revealed that students who used adaptive technologies showed a significant improvement in their science competences compared to those who did not have access to such tools. The personalized approach to science education led to:

• **Improved engagement and motivation** among students, as technological tools made learning more interactive and accessible.

• **Better retention of scientific concepts**, particularly through the use of VR and gamified learning, which allowed students to visualize and manipulate abstract scientific phenomena.

• **Reduction in anxiety** typically associated with science experiments, as virtual environments allowed students to repeat experiments without fear of making irreversible mistakes.

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Pedagogical Implications and Best Practices

Based on the findings, the following best practices for incorporating technology in science education for students with disabilities are proposed:

- **Inclusive curriculum design:** Teachers should integrate technological tools from the outset, ensuring that every student has access to the necessary resources.

- **Collaborative teaching models:** A team-based approach, including science educators, special education professionals, and technology specialists, ensures that all students receive a tailored learning experience.

- **Ongoing professional development:** Teachers need continuous training in the use of new technologies and adaptive learning platforms to effectively support students with disabilities.

CONCLUSION

The integration of technology into the education of students with disabilities, particularly in the natural sciences, represents a critical step toward creating a more inclusive and equitable learning environment. By leveraging adaptive and assistive technologies, educators can help students overcome physical, cognitive, and sensory barriers, allowing them to fully engage with scientific concepts, experiments, and inquiry. This approach not only enhances their scientific competences but also promotes critical thinking, problem-solving, and collaborative skills.

The use of virtual laboratories, AI-powered platforms, and specialized learning tools provides practical solutions for making complex scientific concepts accessible to students with diverse needs. The case studies and examples presented in this article demonstrate that, with the right technological support, students with disabilities can achieve the same level of competence in natural sciences as their non-disabled peers. Moreover, the benefits of these technologies extend beyond the classroom, as they prepare students for future educational and professional opportunities in science-related fields.

To fully realize the potential of these technologies, there is a need for ongoing collaboration between educators, technologists, and policymakers. By investing in adaptive learning environments and ensuring that teachers are equipped with the necessary skills and tools, educational systems can provide all students, regardless of their abilities, with the opportunity to excel in the natural sciences. Ultimately, this approach fosters a more inclusive society where the pursuit of scientific knowledge is accessible to all, empowering students with disabilities to contribute meaningfully to scientific advancements and innovation.

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