SYMPOSIUM - Physics Education in the Digital World

Marilena STREIT-BIANCHI (1), Lars-Jochen THOMS (2, 3), Andreas MUELLER (4)

(1) Vice President ARSCIENCIA, Association registered in Santiago de Compostela, Spain. Member of the Italian Physics Society. Former CERN Deputy Group Leader, 1211 Geneva 23, Switzerland
(2) Chair of Science Education, Thurgau University of Education, Unterer Schulweg 3, 8280 Kreuzlingen, Switzerland
(3) Chair of Science Education, University of Konstanz, Universitätsstr. 10, 78464 Konstanz, Germany
(4) Faculty of Science, Physics Section, University of Geneva, Boulevard du Pont d'Arve 40, 1211 Genève, Switzerland

Abstract. Distance teaching, notably during the recent pandemic, has highlighted challenges in physics and STEM education globally. Efforts are underway to integrate computer-assisted data acquisition, mobile devices, and AI to enhance classroom learning. However, the effective use of digital technologies depends on developing teacher competencies, promoting digital literacy among students, and implementing active learning strategies that incorporate modern physics. This symposium aims to explore sustainable physics education through classroom interventions and teacher development, focusing on integrating modern physics and digital tools with current educational programs.

Introduction

The transition to digital and online learning environments has significantly impacted physics education, amplified by the COVID-19 pandemic's global challenges. This shift necessitates a reevaluation of pedagogical strategies to ensure effective conceptual learning and engagement in the digital age [1]. The current state of physics education underscores a gap between traditional teaching methods and the demands of a digitally native student population. Literature reviews suggest that integrating digital tools, interdisciplinary approaches, and artificial intelligence (AI) can bridge this gap, enhancing both teaching and learning experiences. However, the rapid adoption of digital technologies also presents new challenges, including the need for teachers' professional development, students' digital literacy, and the effective integration of AI into educational contexts.

Specific Problems Considered

This symposium addresses several key problems:

- The need for innovative pedagogical approaches that leverage digital and online environments for enhanced physics education.
- The challenge of integrating interdisciplinary learning to foster a deeper understanding of physics within a broader educational context.
- The development of competencies required by educators to effectively utilise AI tools and resources in teaching.

List of Contributions and Role of Each Contribution for the Symposium

- *“Digital and online environments to foster conceptual learning of physics at high school: a proposal”* presented by Matteo TUVERI, Italy, explores the "Gravitas" program's approach to online physics education through interdisciplinary engagement, integrating the subject with its history and philosophy to enhance conceptual understanding and stimulate interest in STEM fields [2].

- *"Alternative Model of Interdisciplinary STEM Learning: From Theory to Practice"* presented by Marina CONNELL, United Kingdom, discusses AMISL's conceptual framework for integrating physics with other disciplines through project-based and inquiry-based learning methods [3].
- *"Scientific practices in digital settings in secondary science"* presented by Anna LAGER, Finland, discusses the assignments, which guide students to making sense of phenomena through the use of scientific practices in digital settings [4].
- *"What competencies regarding artificial intelligence do (prospective) science teachers need?"* presented by Lars-Jochen THOMS, Switzerland and Germany, analyses the need for AI competencies among science teachers, highlighting the DiKoLAN framework's role in curriculum development [5].

Conclusion

The symposium addresses the pressing challenges of adapting physics education to the digital era, emphasising the need for innovative pedagogical strategies, interdisciplinary approaches, and the integration of AI. Each contribution provides insights into overcoming these challenges, offering practical solutions and frameworks for enhancing the effectiveness of physics education in a rapidly evolving digital landscape. The collective insights aim to guide educators, policymakers, and researchers in developing strategies that not only address current challenges but also anticipate the future needs of physics education.

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Digital and online environments to foster conceptual learning of physics at high school: the “Gravitas” project

Matteo TUVERI

Department of Physics, University of Cagliari, Cittadella Universitaria, 09042, Monserrato, Italy

Abstract. This study explores the "Gravitas" program, an interdisciplinary online educational initiative by the University of Cagliari and the National Institute of Nuclear Physics, aimed at high school students. "Gravitas" integrates physics with its history and philosophy to foster conceptual learning and engagement in STEM. Engaging 250 students from 16 high schools, the project illustrates the potential of online learning to enhance understanding of physics and student motivation.

Introduction

One of the main tasks of teaching is to foster the conceptual transition from a naive interpretation according to personal experience and the common-sense, to an increasingly structured modelling of a disciplinary point of view [1]. Interdisciplinary and informal contexts are the ideal stage to carry on educational experimentations to promote the conceptual learning and engagement in STEM [2]. During COVID-19 pandemic in 2021, many academic institutions moved to remote online teaching, limiting informal learning activities. Research shows that online learning offers the possibility for experts to design activities that are challenging, fresher, creative, and meaningful for students, fostering cooperation and the exchange of ideas among peers [3]. How to design active learning strategies along with informal learning programs in digital environments to promote interdisciplinary and conceptual learning of physics as well as to foster engagement towards STEM?

Methods

To address this question, the Physics Education Research Group of the University of Cagliari and the Cagliari Division of the National Institute of Nuclear Physics designed a specific informal learning and educational online program devoted to high school students called "Gravitas" [4]. The program, launched in December 2021, offered live discussions on gravity with researchers from diverse fields, interactive audience participation via YouTube and Mentimeter, and active learning activities like social media posts creation. Engaging 250 students from 16 high schools, the project investigated the potential of online learning to enhance understanding of physics and student motivation and a possible implementation of Gravitas methodology in schools.

Results and Discussion

Results collected with a research questionnaire [4] show an overall good influence on students’ attitude towards physics, philosophy, and science communication, with higher means in physics with respect to the others. They appreciated experiencing the Gravitas’ online format. Students considered writing posts as useful to better understand the topics covered during the project. They also felt motivated to actively participate in the project and its activities. Future investigations with a larger sample will allow us to infer something general about the positive outcomes of the project.

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Alternative Model of Interdisciplinary STEM Learning: From Theory to Practice

Marina CONNELL

Former University Professor & Teacher, EdTech STEM Strategist in Asian Development Bank funded project, Managing Director at Marina and John Connell Education Ltd., Edinburgh, Scotland, UK

Abstract. The presentation explores the concept of an Alternative Model of Interdisciplinary STEM Learning (AMISL) that does not require any radical initial change to a country's established curriculum. AMISL aims to integrate the four core disciplines of science, technology, engineering, and mathematics, as well as subjects such as geography, economics, physics, chemistry, and art, through Collective Planning, Project-based Learning and Inquiry based learning. AMISL also emphasises the importance of teaching and learning Physics and Artificial Intelligence, especially in relation to the emergence of Large Language Models.

Introduction

To address this Alternative Model of Interdisciplinary STEM Learning (AMISL) as a unique approach which can improve Physics Education, the author reports a pilot-test of AMISL in a Central Asian country.

The Methodology of Alternative Model of Interdisciplinary STEM Learning (AMISL)

The Alternative Model of Interdisciplinary STEM Learning (AMISL) is currently under consideration as a core component of an ongoing major secondary STEM education project in a Central Asian country.

The AMISL approach holds promise as a pedagogical innovation that can reshape the educational landscape and promote student-centred learning. A variety of methodologies are incorporated into AMISL that fosters interdisciplinary learning [1] and teaching [4], including Collective Planning (comprising two parts: General Teacher Planning and Individual Teacher Planning), Project-Based Learning[3] and Inquiry-Based Learning[2]. The key initial aspect in the Alternative Model Interdisciplinary STEM Learning is Collective Planning, involving collaboration among STEM teachers who enrich the specific activities by bringing in their subject expertise/perspective.

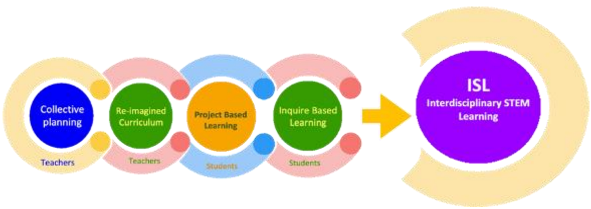

Fig. 1. Variety of methodologies drawn into Alternative Model of Interdisciplinary STEM Learning (AMISL).

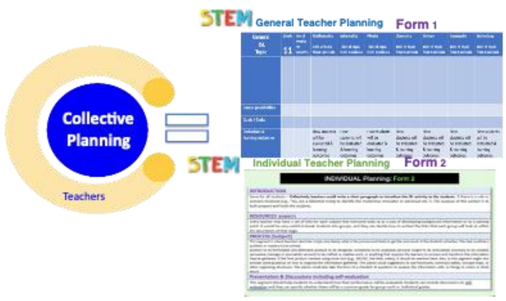

Fig. 2. Collective Teacher Planning involves General Teacher Planning and Individual Teacher Planning.

In summary, AMISL prepares students to tackle real-world challenges and to develop the skills needed for lifelong learning and success in a rapidly changing world.

Physics Education in AMISL complemented by Artificial Intelligence, including Large Language Models

AMISL integrates AI concepts allowing students to explore machine learning, neural networks, and natural language processing. GPT-4 exemplifies one aspect of the power of AI. These models, trained on vast amounts of textual data, can generate human-like responses and perform complex physics tasks. AI apps and websites that AMISL integrate includes:

- *Smodin*. A powerful AI assistant that revolutionises physics homework by simplifying equations and theories, grading assignments, and detecting plagiarism.
- *KerbalEdu*. An engaging physics and engineering learning tool based on the game Kerbal Space Program, where students build rockets and conduct orbital missions.
- *Osmo Newton*. A captivating physics and problem-solving game that uses the device's camera to detect objects and lines drawn by the player to solve puzzles.
- *Pocket Physics*. A valuable education app that offers a comprehensive collection of physical formulas with detailed descriptions and helpful images.
- *Sandbox – Physics Simulator*. A free physics-based game that allows players to create and experiment with different physical phenomena using various objects and materials.
- *ChatGPT*. Uses natural language processing and deep learning to answer, for example, physics questions and explain concepts in a conversational way.
- *Gemini Google*. A creative AI tool that generates physics-related experiments and problems based on the user's input or choice of topic.
- *Albert Einstein AI Tool*. A fun and educational AI tool that lets users interact with a virtual Albert Einstein, who can teach physics concepts, tell jokes, and give advice.
- *Physion*. A web-based tool that enables users to create interactive physics simulations using simple drawing tools and joint constraints.
- *PhET Interactive Simulations*. A collection of over 150 online simulations that cover various topics in physics, such as motion, forces, energy, waves, electricity, and magnetism.

Summary

The presentation proposes an Alternative Model of Interdisciplinary STEM Learning (AMISL) that promotes student-centred and interdisciplinary learning and does not require any radical initial change to a country's established curriculum, offering a conceptual framework to guide its design and implementation. A pilot-test implementation of AMISL is under way in a Central Asian country.

In relation to the emergence of Large Language Models (LLMs). AMISL also suggests some ways of integrating Physics and AI, such as using simulations, games, chatbots, and creative tools.

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Scientific practices in digital settings in secondary science

Anna LAGER (1), Jari LAVONEN (1, 2)

(1) Faculty of Educational Sciences, University of Helsinki, Siltavuorenpenger 5, 00170, Helsinki, Finland
(2) Department of Childhood Education and Centre for Education Practice Research, University of Johannesburg, Soweto, South Africa

Abstract. Aim of science education has shifted from students' knowledge of science content to learning of usable knowledge while making sense of phenomena through engaging in scientific practices. Though science learning in digital settings has been researched in the literature, there is still a lack of understanding how to design assignments that support students' in making sense of phenomena by employing scientific practices, such as planning investigations and making evidence-based conclusions. In this study, we explore the assignments, which guide students to making sense of phenomena through the use of scientific practices in digital settings.

Introduction

Scientific practices (SPs) reflect the multiple ways in which scientists explore and understand the world and are similar to expert performance in science. The focus on the use of SP in making sense of phenomena emphasises the connection between doing and learning [1]. "Doing science" is often considered to happen only in the laboratory, but science education requires a far wider context. In Barbazzeni's study [2], the insights from scientists serve as a call to action for educators to better prepare students for future careers in the digitally evolving landscape. At the same time, the recent pandemic brought to light the challenges associated with teaching and learning in digital settings. This study aims to explore how students' use of SPs can be supported through specific assignments in digital settings.

Theoretical framework

In our study we follow the sociocultural perspective, i.e. knowledge is constructed through the interdependence of participants interacting with each other and with tools and objects in their environment [3]. The digital tools should allow students to engage with knowledge for the purpose of making it actionable [4] and form usable understanding.

Methods and findings

In collaboration with teachers, we designed collaborative assignments for upper secondary physics. Assignments were inquiry-based and required the use of SPs and multiple digital resources (Table 1). The teachers implemented the assignments as part of their teaching in a remote setting. Students worked collaboratively on the assignments in small groups and recorded their screens. The collected screen-recording data revealed the "hidden moments" of the learning process and use of SPs. Afterwards, participants took part in semi-structured interviews focused on students' perceptions in terms of using SPs and use of digital resources.

Table 1. Example of the assignment with the targeted scientific practices and possible digital tools.

<table>
<tr><th>Assignment</th><th>Scientific practices</th><th>Possible digital tools</th></tr>
<tr><td rowspan="3">1) Investigate digital lab “Bouyancy”. Observe what happens to the weight when the block is under water and under oil oil. Write your observations.
2) Explain the reasons for differences in the observed weights. You can support your explanations with the graphic visualisation (e.g. net force).
3) Based on your digital lab observations and explanation, how could we find the density of unknown liquid? Write the plan of the experiment.
4) Perform a digital experiment to find oil’s density. Make a short report with collected data presented in tables/graphs and conclusions. Analyse the result and used models.</td><td>Obtaining information; Asking questions</td><td>Digital laboratories and simulations; Online word processor</td></tr>
<tr><td>Constructing explanations; Developing and using models</td><td>Online word processor; Graphics editor</td></tr>
<tr><td>Planning and carrying out investigations; Using mathematics and ICT; Communicating information</td><td>Digital laboratories and simulations; Interactive calculus application; Online word processor;</td></tr>
</table>

The findings showed that the discussions and use of digital resources preceded and supported SPs and the sense making of phenomena. The data revealed that most challenges were related to such SPs as building models, developing explanations, and planning investigations. The students perceived the designed assignments and related SPs positively and reported interest and an appropriate level of challenge and skills, which allows us to assume that situational engagement took place [5].

Conclusion

This study sheds light on the ways how the interplay between use of SPs and digital tools can be realised through specific assignments in digital settings. The findings emphasise the importance of integrating collaborative opportunities and digital tools and resources into the assignments to support use of SPs. Digital tools can be used to support challenging SPs [6], for example, the simulations can illustrate the idea of models and limitations, as well as contextualise the abstract concepts. Interrelatedness of SPs points to the need of designing assignments that incorporate multiple SPs.

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What competencies regarding artificial intelligence do (prospective) science teachers need?

Lars-Jochen THOMS (1, 2), Sebastian BECKER-GENSCHOW (3), Till BRUCKERMANN (4), Alexander FINGER (5), Johannes HUWER (1, 2), Erik KREMSER (6,2), Monique MEIER (7), Christoph THYSSEN (8), Lena VON KOTZEBUE (9)

(1) Chair of Science Education, Thurgau University of Education, Kreuzlingen, Switzerland
(2) Chair of Science Education, University of Konstanz, Konstanz, Germany
(3) Digital Education, University of Cologne, Cologne, Germany
(4) Institute of Education, Leibniz University Hannover, Hannover, Germany
(5) Institute for Biology, Biology Education, Leipzig University, Leipzig, Germany
(6) Department of Physics, Technical University of Darmstadt, Darmstadt, Germany
(7) Chair of Biology Education, Technical University of Dresden, Dresden, Germany
(8) Biology Education Research Group, University of Kaiserslautern, Kaiserslautern, Germany
(9) Biology Education, School of Education, University of Salzburg, Salzburg, Austria

Abstract. Since ChatGPT became available to the public, it has become the fastest growing application (in terms of registered users). The reception in social media and mass media is correspondingly large. There is also extensive discussion among teachers at universities and schools about how to deal with ChatGPT. The spectrum here ranges from a desire for bans to overoptimistic assessments of the potential and a corresponding desire for the fastest possible integration into teaching practice. It is critical to observe that the terms “ChatGPT” and “artificial intelligence” are often equated and ChatGPT takes a prominent representative position for applications of artificial intelligence (AI). This paints a simplistic, one-sided picture of artificial intelligence, which further complicates the urgently needed discussion of the opportunities and risks of using artificial intelligence in the classroom, in university teaching, and especially in teacher education (pre-service and professional development), as well as in society. In the presentation, a broader concept for the curricular embedding of AI-related competencies in science teacher education based on the DiKoLAN (Digital Competencies for Teaching in Science Education) framework will be discussed.

Introduction

Artificial Intelligence (AI) has become a significant part of daily life and work, marking itself as a key technology of the 21st century. Its impact on society, especially within the education system across all levels, is expected to grow. AI-based applications offer the potential to enhance teaching and learning processes and make educators' tasks more efficient. AI can impact education at three levels: individual learners (e.g., self-directed learning, practice, and training), classroom level (e.g., learning analysis, collaborative learning, individual support), and school level (e.g., performance predictions, school planning). However, these opportunities come with significant risks, such as data protection, security, and potential bias due to flawed training data. It is to be expected that ethical and social issues will be immanent. Therefore, AI systems used in schools need to be trustworthy and fair, placing a responsibility on educators to ensure their safe and beneficial use.

The European Commission emphasises the critical role of teachers and school administrators in successfully implementing AI systems in education [1]. They highlight the importance of educators understanding the opportunities and challenges of using AI to improve teaching, learning, and assessment. Consequently, AI-related competencies should be integrated throughout all stages of teacher education, aligning with The German Standing Conference of the Ministers of Education and Cultural Affairs’ addition to the strategy “Education in the

Digital World", which suggests adapting teacher training to include future-oriented competencies in AI, Big Data, automated decision-making systems, virtual reality, and data protection [2]. This integration not only provides competencies but also helps reduce apprehensions towards this new technology, potentially increasing its implementation in regular teaching.

Artificial intelligence requires more than technical knowledge

Beyond technical knowledge, the DiKoLAN framework systematically identifies digital basic competencies for prospective science teachers, offering a structured approach to teaching in line with the spiral curriculum concept [3]. However, the rapid advancements in AI and its profound implications across all aspects of life necessitate expanding existing models like TPACK to incorporate sociocultural knowledge (SCK) in the context of digitality. The DPACK model suggests considering the interconnections of technological and sociocultural knowledge when reflecting on AI's significance for competency areas in DiKoLAN [4].

Digital Competencies for Teaching in Science Education related to Artificial Intelligence

Given the transformative processes associated with AI advancements, the question arises on how to integrate AI-related competencies within the DiKoLAN framework for prospective science teachers. It seems more appropriate to derive relevant AI competencies as specific, operationalized individual competencies within DiKoLAN's existing competency areas by checking where AI can be relevant rather than introducing "Artificial Intelligence" as a standalone category. This approach allows DiKoLAN to be applied successfully in reflecting on new technologies like AI in science education, structuring teacher training for future technologies.

Conclusion

Future teachers will need comprehensive competencies in utilising AI in education. For science subjects, this includes both interdisciplinary and subject-specific AI competencies. DiKoLAN serves as an efficient tool for structurally analysing, organising, and mapping AI-related competencies into curricula for science teacher education, highlighting the need for ongoing development in this area.

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