Can. J. Sci. Math. Techn. Educ. (2022) 22:1002–1005
https://doi.org/10.1007/s42330-022-00233-2

UNIVERSITY OF TORONTO
OISE | ONTARIO INSTITUTE FOR STUDIES IN EDUCATION

COMMENTARY

Check for updates

Teaching–Learning Contemporary Physics: from Research to Practice

Sri Wahyuni[1] · Andreas Suparman[1] · Windy Kasmita[1]

Accepted: 17 September 2022 / Published online: 7 October 2022

Abstract As part of Springer, the edited book addresses innovative approaches and pedagogical strategies, the development of effective methods for assessing, and the innovative project in teaching and learning contemporary physics. This volume includes successful experimental and theoretical studies of QM teaching, which the experts or teachers can then adopt or modify the concept into practice in context. The 19 chapters, representing results of original study works dealing with Physics Education, are selected from the contributions in a conference on the teaching and learning of quantum physics. The goal of the book is to introduce contemporary physics to all level schools. Without a doubt, the book is recommended for high school teachers, instructional developers, and scientists to explore and develop the theories, approaches, and strategies in the book to advance teaching/learning of CP.

Résumé Cet ouvrage révisé publié chez Springer traite des approches et des stratégies pédagogiques innovantes, du développement de méthodes d'évaluation efficaces et du projet novateur dans l'enseignement et l'apprentissage de la physique contemporaine (PC). Ce volume comprend des études expérimentales et théoriques concluantes sur l'enseignement de la PC, que les experts ou les enseignants peuvent ensuite adopter ou modifier dans la mise en pratique contextuelle du concept. Les 19 chapitres, qui représentent les résultats d'études originales traitant de l'enseignement de la physique, sont sélectionnés parmi les contributions faites lors d'une conférence sur l'enseignement et l'apprentissage de la physique quantique. L'objectif du livre est d'introduire la physique contemporaine dans les écoles, et ce à tous les niveaux. Il est sans aucun doute recommandé aux enseignants du secondaire, aux développeurs de systèmes éducatifs et aux scientifiques d'explorer et d'approfondir les théories, les approches et les stratégies présentées dans l'ouvrage afin de faire progresser l'enseignement et l'apprentissage de la PC.

Keywords Quantum mechanics (QM) · Contemporary physics (CP) · Modern Physics · Innovative approach · Active learning · All level education · Innovation in learning

✉ Sri Wahyuni
yunnisw@upi.edu

Andreas Suparman
andy-suparman@upi.edu

Windy Kasmita
windykasmita@upi.edu

[1] Universitas Pendidikan Indonesia, Jl. Dr. Setiabudi No. 229, Kelurahan Isola, Kecamatan Sukasari, Kota Bandung 4015, Indonesia

Challenge in Physics Education is a series of books in Springer that describes new approaches and perspectives and offers current innovations to enhance teachers' and students' activities in teaching/learning contemporary physics (CP). The series consists of three books offering a wide range of topics that highlight fundamental interplay between research and innovation in teaching CP.

The edited book, Teaching-Learning Contemporary Physics: from Research to Practice (Jarosievitz & Sükösd, 2021), is part of Springer's "Challenge in Physics Education" series addressed to professional readers including researchers, teachers, instructional designers, and pre-service teachers. The book comprises five parts including 19 chapters that clearly explain contemporary physics topics, specifically teaching and learning quantum physics, Roland Eötvös and the principle of equivalence, experimentation, PER and assessment impact, active learning, and innovative project. The book impressively provides deep research and detailed explanations in each chapter.

This book opens with a discussion of the physics education research (PER) finding that historical approach, formal structural approach, and conceptual approach are three main approaches to design contents. The approaches are presented as an extensive research bibliography to explore the basic contents of organized quantum mechanics (QM) on a disciplinary level for education. In the bibliography study, they claim the importance of giving space for learners to understand the basic concept and formalism of QM. Thus, by fully understanding the approaches, teachers can provide resources for teaching QM and integrate coherent content of QM with the curriculum.

One of the hardest things about teaching or learning QM is that it requires substantial mathematical knowledge. Quantum Cryptography is introduced as an approach for teaching QM in chapter 2 to reduce the complexity, yet still, promote a deeper understanding of QM. As Quantum Cryptography can bring quantum information into practice in school, students can build their comprehension by doing inquiry activities. Moreover, statistical behavior, interference of single quantum objects, unique measurement results, and complementarity are formulated as reasoning tools in chapter 3. The tools can facilitate quality learning of quantum physics, predict quantum mechanical effects, and help students to face learning difficulties. The tools are used to develop quantum physics concepts with fewer mathematical formulas.

Mathematics and natural sciences, especially physics, are structurally related, and commonly learners need to have good basic mathematics to understand the formula of contemporary physics (CP). In chapter 4, the visualization of the Dirac formalism and two teaching/learning proposal (TLP) are successfully implemented to enhance students' skills to understand, interpret, and implement the fundamental concepts of CP, and its interplay with mathematics. Inquiry-based learning, intentional and systematic visualization of the formalism, and active learning methods are strategies to assist students to understand mathematical structures and concepts for CP. Furthermore, to successfully incorporate CP in the physics curriculum, in chapter 5 teachers need to combine four steps: preparation of the hands-on module, practical teacher training, research on implementation in the classroom, and redesign of the unit. The chapter also provides a few successful examples of the role of analogies in introducing CP to pre-university-level education.

The development of modern physics cannot be separated from Baron Roland Eötvös, a Hungarian experimental researcher, discussed in part 2. This part involves two articles discussing Eötvös and the principle of equivalence. In chapter 6, the authors explain his scientific achievements in gravitational interaction and applied geophysics experiments. They also explore his work on developing the contemporary education system in Hungary, which became the foundation to build an innovative teacher training institution. In addition to his achievements, chapter 7 discusses gravity versus gravity derived from the equivalence principle and its careful confirmation by Roland von Eötvös.

Experiments are an indispensable ingredient in scientific investigations and have a central role in teaching physics. As physics is a science based on experiences, observations, and experimentally found facts, students need to design, develop, and conduct experiments in class to better understand the specific physics topics. In chapter 8, the Sydney University Physics Education Research (SUPER) shares research in the Australian context and formulates advancing science and engineering through laboratory learning (ASELL) to design and assess the effectiveness of experiments, and measure students' experience with experiments. By doing the experiment, students also can integrate and organize their previous knowledge in understanding the new concepts of physics. In chapter 9, the authors explain the term "transfer of learning" or "the learning cycle" to understand how prior knowledge contributes to students' comprehension in the bright green LED experiment.

Laboratory activities can help students acquire, integrate, and construct knowledge in a friendly way (Stern et al., 2017). To make learning more effective and enjoyable, in chapter 10, the authors develop a teaching–learning sequence (TLS) on thermal phenomena and irreversibility based on the dice and coin model. TLS can be utilized as a hands-on game activity and as a computer simulation for secondary school students. They tested it in secondary school and found that TLS increased participation among all students, energized diverse students, enhanced lab and game sessions, and expanded dimensions related to historical discussions.

The effectiveness of experiments in the teaching of physics is difficult to measure. Evaluation can be greatly affected by the instrument used, and performance studies may also be affected by the way in which the evaluation is done. In chapter 11, the authors explain Lawson's Classroom Test of Scientific Reasoning (LCTSR) that is widely used to measure students' scientific reasoning. LCTSR was investigated with Rash analysis to determine the effectiveness of the scoring model. The analysis showed that all three assessing methods gave statistically inconclusive results. However, the LCTSR can be advanced by adding more items to the LCTSR and by combining two-layer problems with single-layer thought pairs. Additionally, in chapter 13, the authors presented the concept of force in the form of a multiple-choice quiz to assess students' understanding of the concept's Newtonian mechanics. This pilot study demonstrates that students' responses to force concept measures can be investigated using a cluster analysis approach to investigate their understanding of Newtonian mechanics.

As a central role in teaching physics, laboratory activities require a high comprehension of the content and process of physics, and a specific form of knowledge of educational content. Due to these considerations, teachers often feel uncomfortable in the lab because they lack the skills that make hands-on work useful for learning. In light of these considerations, in chapter 12, an in-service teacher training program is designed to improve physics teachers' competencies for applying physics practicum in secondary school. Practice refers to a science teaching and learning activity in which students individually or in small groups observe and/or manipulate the objects they are studying. Results indicate that content presentation, practice, research, action research, adequate study time, and community are characteristics that contribute to positive change in carrying laboratory activities to class.

Experiments in teaching physics promote active learning by engaging students' experience with observation, tests, and application. Social constructivist theory highlights the significant influence of social interaction, culture tools, and students' activities in active learning. The methods and strategies of active learning are known to improve conceptual understanding of students in many subject areas. Due to these reasons, active learning is highly recommended by teachers and professors to advance traditional teaching methods. In chapter 14, the authors describe the results of an activity-based physics suite known for several developments in active physics learning. The successful models are elaborated for the dissemination of active learning strategies, tools, and curricula. In addition, systematic analyses of mental processes, new approaches to active learning, and experiences in implementing active participatory approaches and research-based learning methods are studied to share the contribution of chapter 15 to the field of research on active learning.

What is interesting in this book is this book does not only share theories and research in the field of physics study, but it also provides innovative projects in part 5. In chapter 16, the authors develop and test an innovative K-6 science education program to develop a coherent vertical curriculum for preschool and elementary teachers. The Max's Worlds project, based on a conceptualizing approach to teach CP, relies on metaphorical and analogical reasoning and stories about the forces of nature. The project achieved positive results in students' understanding of energy concepts. Another project is under development and testing, called TECNOArtea in class 17. TECNOArtea aims to develop the creativity of dual exceptional students through the Problem-Based Learning Program (PPL). The project positively influences students' creativity and supports an informal problem-based science program to promote students' creativity in diagnosing an anomaly.

Chapter 18 of this book recommends that teachers use 3D-printed plasma electron guns to study the characteristic of particles in electric and magnetic fields. Compared to earlier experiments, called cathode ray tubes (CRTs), 3D-printed plasmonic electron guns are cheaper and more readily available. An easy-to-use electron beam resource is provided to conduct beam generation, beam focusing, and beam deflection experiments in hands-on classroom activities. Also, inspired by the macroscopic investigation of Gekko's behavior, the authors proposed a new tribological teaching and learning sequence in the last chapter to teach structural properties, especially nanoscience. The sequence was assessed and gives positive findings to learn the characteristic of particles.

Overall, the book succeeds in providing good studies in each chapter. Each chapter has clear research questions, appropriate research methodology, relevant and empirical data, and proper data analysis; acknowledges previous research on the topic and its limitation; and provides suggestions for future research. The book also successfully explains an overview of how different strategies are used to teach QP at different levels of education and provides a rich perspective for developing appropriate assessment and innovation programs. The book also serves perspective not only from European authors and contexts, but also from other countries such as Australia, Israel, and the USA.

Therefore, if you are a physics teacher and eager to advance your skill in designing and teaching contemporary physics, we suggest you read this book. The book is also recommended for physics education researchers who need a guide for conducting in the field of teaching and learning quantum mechanics.

Acknowledgements The authors would like to express their deepest gratitude to Lembaga Pengelolaan Dana Pendidikan (LPDP/Indonesia Endowment Fund for Education) under the Ministry of Finance of the Republic of Indonesia as the sponsor for their masters' studies, and the support of this publication. We thank our mentors Fikri Yanda, Frida Akmalia, and Yunita Laila Zulfa from Universitas Pendidikan Indonesia for mentoring and editing the manuscript.

Declarations

Conflict of Interest The authors declare no competing interests.

References

Jarosievitz, B., & Sükösd, C. (2021). *Teaching-Learning Contemporary Physics: From Research to Practice.* Springer: Switzerland.

Stern, C., Echeverria, C., & Porta, D. (2017). *Teaching Physics Through Experimental Project*. Procedia IUTAM. https://doi.org/10.1016/j.piutam.2017.03.026.