Model-based learning analytics for capturing and scaffolding students' problem-solving skills in technology-enhanced learning environments

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Abstract

Despite educators ' best efforts, PISA results show that many students lack problem-solving skills. Students face difficulties at all stages of the solution process, from understanding the problem to planning and executing strategies and reflecting on the solution. This complexity is compounded by the diverse cognitive architectures and problem-solving strategies among learners. Although teachers know strategies to support problem-solving, these are rarely applied in classrooms, and there is less emphasis on developing higher cognitive skills. Current learning analytics (LA) systems primarily focus on behavioral data, leading to a disconnect between data and educational theory. There is a need for integrating adaptive scaffolding in learning environments to support teachers in making informed decisions to scaffold student problem-solving. This PhD research proposes using model-based learning analytics to bridge the gap between data-driven technologies and teacher decision-making, aiming to enhance students' problem-solving skills in physics through adaptive scaffolding systems.

Keywords

Problem-solving skills, Model-based Learning Analytics, Adaptive Scaffolding, Pedagogical Models,

1. Introduction

Despite continuous efforts to enhance problem-solving skills among students, PISA results indicate that many students still struggle in this area [1]. They face difficulties at various stages of the problem-solving process, including understanding the problem, selecting appropriate strategies, planning and execution, and reflecting on the solution [2]. The diversity in students' cognitive architectures and problem-solving strategies complicates effectively teaching these skills [3]. While insufficient problem-solving ability is not always due to a lack of domain knowledge, performance is often undermined by ineffective activation of knowledge resulting from instructional methods [4]. Although teachers are aware of teaching strategies to support problem solving, these are rarely applied in the class [1] and less attention is paid to the development of students' higher cognitive skills [5]. While teachers might be aware of students' different levels of thinking and reasoning, they are seldom equipped to understand or design appropriate pedagogy to lead students towards a deeper understanding of a specific concept, such as problem-solving skills. One of the main challenges identified in the research is the gap in teachers' ability to design teaching strategies that accommodate varying skill levels, especially when using learning technologies [6]. The dedicated section (highlighted later in this paper) on supporting teacher adoption addresses this challenge by exploring how teachers can be supported in integrating pedagogical models with technological tools. This alignment is necessary to successfully implement adaptive scaffolding and model-based LA systems. The traditional approach to teacher education emphasizes fundamental teaching knowledge and skills, but can focus less on embedding cognitive elements into the learning process. This is called by Bond and Bedenlier [7], as interconnectedness of technology, teachers, and students. The complexity of teaching problem-solving skills aggravates that. Given the diverse cognitive architectures and problem-solving strategies, among learners, creates a gap in teacher's ability to design strategies that accommodate varying skill levels, especially when using learning technologies [3, 6]. While digital technology, by itself, does not necessarily lead to improved student results or HOTSs, it may be used to reinforce pedagogical factors shown to have a positive impact. Combining innovative use of technology and learning methods derived from socio-cultural learning theory, can foster the students' depth of mathematical understanding [8]. At the same time, learning technology can also provide feedback to help teachers gain insights into students' learning process and shape future instruction. These uses of technology, however, require teachers to design learning tasks that successively lead students to higher-order thinking processes [9]. Given the current state of teaching in problem-solving, this would require scaffolding, embedded in our learning environments, that structure activities, artifacts and computational tools in a synergistic way [10]. However, a lot of learning analytics (LA) systems focus mainly on behavioral data (e.g., number of clicks) and teacher role is undefined in those systems, indicating that teachers' perceptions about such tools is not always useful or helpful leading to actionability and informed decision making [11]. Disconnection between behavioral data and educational theory results in the atheoretical, context-less collection, analysis, and reporting of student data, which does not enhance educational practice and research [12, 13]. There is a need for integration between current adaptive and LA technologies to support teachers in making informed decisions to scaffold student problem-solving. Although digital technology alone does not necessarily improve student's learning outcomes, or problem-solving skills, it can reinforce the underlying pedagogical factors. More importantly, technology can provide feedback to help teachers gain insights into student's learning processes, and shape future instruction, which requires teachers to design tasks that successively develop students' complex cognitive processes [9]. Given the current state of teaching these skills, effective implementation of adaptive scaffolding embedded in the learning environment is necessary, in order to synchronize

Proceedings of the Doctoral Consortium of the 19th European Conference on Technology Enhanced Learning, 16th September 2024, Krems an der Donau, Austria

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activities, artifacts and tools synergistically [14]. Earlier research shows that adopting technology-enriched practices is a social process where teachers develop an understanding through partnerships with researchers [15, 16]. These collaborations allow for co-creating and refining instructional strategies, making technology integration meaningful and relevant. Participating in training programs that integrate technology, pedagogical concepts, and student data through LA dashboards helps teachers interpret classroom data and translate it into teaching strategies. Physics inherently involves complex problem-solving that integrates both conceptual understanding and mathematical reasoning. Students are required to apply abstract concepts to real-world phenomena, analyze multiple variables, and often deal with ambiguous or open-ended problems. This complexity demands higher-order thinking skills and metacognitive strategies, essential to effective problem-solving. As noted in my research, complex problem-solving requires effective interaction between the learner and tasks, employing cognitive resources and domain knowledge [17, 18]. While training and a pedagogy-grounded dashboard are a good start, teachers need ongoing support to effectively use these tools to provide adaptive scaffolding for different profiles of students during the problem-solving process. This PhD research proposes using model-based learning analytics to bridge the gap between data-driven technologies and teacher decision-making, aiming to foster the development of students' problem-solving skills (PSS) in physics through adaptive scaffolding systems. While systems that adapt instruction based on prior knowledge, errors, and misconceptions have proven effective [13], current examples are designed for highly-structured learning settings in narrow domains, rather than for more transferable, higher-order skills, or they are primarily data-driven [17, 19]. The aim of this PhD is to conceptualize model-based learning analytics for enhancing problem-solving in primary school settings. The research questions guiding this PhD are:

- What are the specific learner data measures that indicate the problem-solving ability of students?
- What design features of a teacher dashboard can enable adaptive scaffolding to better identify challenges and support teachers in developing students' problem-solving skills?
- What is the effect of the proposed system and scaffolding strategies, delivered through a model-based LA infrastructure in authentic classroom settings, on teacher decision-making and the development of students' problem-solving skills in physics?

2. Theoretical Framework

2.1. Student's problem-solving skills

Complex problem-solving is an important cognitive skill that involves addressing dynamically changing and often ambiguous problems [18]. It requires the integration of cognitive, emotional, and social resources to navigate and resolve issues that are not straightforward and involve multiple interrelated elements. Technology can aid this process, as students in technology-enriched classrooms demonstrate significantly better problem-solving abilities compared to those in traditional settings [20]. This improvement is partly due to personalized learning experiences that consider individual student needs [21]. Additionally, complex problem-solving requires effective interaction between the learner and tasks, employing cognitive resources and domain knowledge [17]. Similarly, Bond and Bedenlier (2019) [7] discuss cognitive, metacognitive, and motivational aspects, indicating that successful academic problem-solving requires a blend of cognitive strategies, knowledge components, and motivational skills. Due to this, these problem-solving skills are often understood through their application in educational contexts, not necessarily by their definition(s) [22]. Consequently, while the methodologies themselves are critical, educators and researchers should acknowledge the varied nature of problems across different domains (like physics and mathematics) and the implications for instructional design, underscoring the critical role of the medium and domain in shaping problem-solving abilities [19] and the importance of both domain-specific knowledge and domain-general cognitive abilities for effective problem-solving [18]. The developed cognitive and technological models need to be taken further by finding variables produced in everyday classroom situations that hint at complex problem-solving skills [23, 20]. This means that the computer agent (for example, an open learning environment) and the teacher are both pivotal in scaffolding the student's learning since computer-only scaffolding can only positively affect learning [20]. As shown in the meta-analysis by Kim and others (2018) [23], while adaptive scaffolding models have focused on supporting individual cognitive processes and facilitating problem-solving, scaffolding is needed to support metacognitive skills. Moreover, this includes developing more sophisticated models of learner cognition and problem-solving behaviors to guide scaffolding design and exploring how different forms of scaffolding (e.g., peer, teacher, and technology-enhanced) interact within complex classroom dynamics. Such interactions between students, teachers, and computational agents allow us to explore not only the development of students' problem-solving skills but also the process and understanding of the elements that help students develop their skills through advances in the LA and AI field [24]. Today, we have developed the expertise to predict a validated construct (for instance, problem-solving skills) through the educational data (from task interaction) collected during the learning process, improving student learning outcomes. This wave of seamless integration of LA also has a darker side; competent teachers are in danger of displacement due to a lack of digital skills [25], amongst other factors. Thus, efficient support for teachers is needed to understand the data LA solutions provide and make meaningful decisions [25, 24]. The study of Ley and others (2023) [26] highlights the importance of blending the LA solutions and pedagogical concepts so that teachers can benefit from the data, keep teachers in the loop, and promote actionability. Current systems predominantly focus on cognitive aspects of learning, such as knowledge states, often neglecting social and collaborative learning processes. Model-based LA involves using models of student learning and instruction to make educational processes transparent to teachers. As such, it should aim to couple the knowledge used by intelligent learning systems with the knowledge used by teachers in classroom decision-making [26]. By making models transparent, teachers can gain theory-driven insights into student learning, making the data actionable and meaningful. Despite the potential benefits, many model-based LA systems still need to be integrated effectively in classroom settings. In conclusion, systems should provide feedback based on pedagogical and psychological models, helping teachers understand student progress and tailor instruction accordingly. Additionally, teachers should be actively involved in the design, implementation, and evaluation phases of LA systems to ensure the systems are practical and beneficial in real educational contexts.

2.2. Supporting teacher adoption

Earlier research [15] has shown that adopting new technology-enriched practices is a social process. Teachers develop an understanding of innovations through teacher-researcher partnerships. These partnerships allow teachers to co-create and refine instructional strategies for students, making sure technology integration is meaningful and relevant. Participating in structured training programs focusing on data literacy and Learning Analytics (LA) dashboards helps teachers enhance their understanding and use of data-driven practices [27]. Teachers in such programs learn to interpret and use classroom data, developing a deeper appreciation for data's role in instructional decisions. This finding supports the idea that effectively adopting technology in education requires ongoing professional development and support systems. These systems help teachers engage with new practices. Teachers can improve their teaching methods and outcomes by fostering an environment for collaborative exploration and implementation of data-informed strategies. Again, the problems teachers face regarding adopting technology in classrooms are manifold - from limited technological and pedagogical knowledge and inadequate professional development [16] to social dynamics and certain feedback and support systems [11]. Furthermore, digital competence in using novel tools is a difficult skill to foster and use in a classroom. For those reasons, addressing the challenges that teachers face regarding the adoption of technology in the classroom requires adaptive scaffolding in learning environments, where learning activities, tools and resources are seamlessly aligned [15]. The difficulty lies in creating this seamless integration for each specific problem-solving task, tailored to match the problem-solver's unique profile while ensuring the approach remains transparent and manageable for teachers. The teacher's skill to tackle the issue of teaching problem-solving skills effectively lies in their digital competence [11] but also in their knowledge and ability to apply pedagogical frameworks. All in all, it is important to state the complexity of the topic, and the lack of a more holistic approach of embedding pedagogical models already in the design phase of technology adoption. The undeniable potential of LA can be hampered by the limitations observed in its practical implementation, such as insufficient grounding in educational theory or the lack of relevance to the teachers' specific needs. The solution could be a model-based approach incorporating pedagogical, social and technological concepts in its design and subsequent implementation. In summary, the research gap lies in the lack of emphasis on designing engaging learning experiences in teacher education, especially when integrating technology. The complexity and diversity of learning situations and students' cognitive processes make it difficult to balance and integrate the roles of teachers, technology, and students in teaching problem-solving skills. Consequently, teachers often struggle to design and implement strategies that meet diverse learner needs due to limited technological and pedagogical knowledge. Addressing these gaps requires adaptive scaffolding, ongoing professional development and a model-based approach that integrates pedagogical and technological concepts.

3. Methodology

3.1. Research Design

A Design-based Research Methodology (DBR) [28] with a strong focus on co-creation and interventions in field settings (schools). The cyclical nature of design-based research allows revisiting previous stages of the research to validate concepts or collect more data. Due to the many-faceted models in the PhD research, each model component needs its own design process, which facilitates design-based research. The first phase of the research is focused on developing a pedagogical model and data collection model for fostering the development and monitoring of students' problem-solving skills in physics. A domain model for physics lessons was designed for on-task assessment of students' thinking processes. A model is embedded into the authoring system of DLRs to scaffold the design of tasks to foster the development of PSS. As the design of tasks and development of students' problem-solving skills, also depends on teaching methods and learning activities, tasks are integrated into the TEL environments based on the ICAP framework. Drawing on pedagogical and domain models, a technological infrastructure is proposed using the H5P-based authoring system to capture students' problem-solving processes. In the second phase, smaller scale piloting in the authentic classroom settings was conducted to validate the pedagogical model, data collection model and technical infrastructure to derive the initial scaffolding strategies. The results from the initial iteration (see also section 4) will inform refinements to the models and infrastructure. In the third phase, a model-based LA dashboard will be developed in this phase based on the data collected in the authentic classroom settings. The dashboard will integrate a pedagogical model with LA to make the learning process transparent and meaningful for teachers [26]. This approach helps teachers understand how students' data relates to pedagogical concepts and supports informed decision-making. For our purposes the pedagogical model was problem solving skills. The dashboard will offer different levels of granularity that helps in reducing cognitive load and ensuring that teachers can access the most relevant information efficiently. The dashboard will incorporate features that support adaptive scaffolding, helping teachers identify students' needs and provide appropriate support. This helps teachers in adjusting teaching strategies based on real-time data. These principles aim to reduce the cognitive load for teachers and enable informed, real-time decisions. The dashboard will be evaluated and subsequently designed together with the teachers. Taking into account recommendations for improving the dashboard and its integration into classroom practices. Thus, it might be necessary to test the dashboard numerous times. In the fourth phase, a quasi-experimental classroom intervention will be conducted to validate scaffolding strategies, assess teacher decision-making using the model-based learning analytics infrastructure in authentic settings, and evaluate its impact on students' learning. This phase assumes that the use of scaffolding strategies in authentic classroom settings can significantly impact both teachers' decision-making processes and the development of students' skills. Thus our evaluation of the teacher dashboard will aim to explore various scaffolding strategies employed in different educational contexts and their effects on teacher decision-making and student skill development. Finally a validated conceptual model is proposed together with design principles and prototypical dashboards.

3.2. Data Collection

Data collection will focus both on teachers and students. In different phases, we will collect different types of data for different purposes. Students' problem-solving skills are assessed using the MAPS rubric to align tasks with specific skills [29]. Digital tasks are categorized according to levels of problem-solving skills (PSS), and student interactions with these tasks enable ongoing monitoring of skill development within our framework. Furthermore, we collect data on students' domain knowledge and self-reported meta-cognitive strategies [30]. These three components - domain knowledge, meta-cognitive strategies and problem-solving skills - constitute the foundation of our pedagogical model, integrated with various data sources across different time points. Students' skills and conceptual understanding will be evaluated with pre- and post measures. Additional data is collected about students' individual characteristics, attitudes and beliefs. To explore teachers' professional learning experience, pre- and post measures and reflective diaries will be used to understand how the developed dashboard improves teachers' understanding of students' problem-solving skills, awareness of scaffolding strategies and improved and informed decision making. The final intervention with teachers requires a longer intervention, which is preceded by measures of baseline data, such as pretest assessments for students' problem-solving skills and teachers' decision-making strategies. The data collected during the intervention is many-fold. Evaluating the intervention will include both teacher and student-focused measures. For teachers, we will track the frequency and type of dashboard usage, monitor changes in decision-making strategies through reflections, journals, and interviews, and assess their satisfaction and perceived utility of the dashboard via surveys and interviews. For students, we will measure improvement in problem-solving skills using pre- and post-tests and formative assessments, and evaluate their engagement and motivation in learning activities through surveys and classroom observations.

4. Initial Results

The first iteration of the DBR cycle was conducted in 2023 with the aim to answer the first research question: What are the specific learner data measures that indicate the problem-solving ability of students? We conducted an intervention study in a classroom setting teaching environment with two groups of primary school students. A total of 75 students, aged 14-15, participated in the study, with a balanced mix of males and females. The study focused on the physics topic of light and reflection over a duration of 3.5 hours, facilitated by one teacher-researcher. The tasks were designed using H5P templates to foster complex problem-solving skills, with tasks gradually increasing in difficulty and incorporating fading scaffolds. Initial tasks were less difficult, such as multiple-choice questions, progressing to more complex, open-ended tasks. Various media, interactive scaffolds and guided questions were used to support complex thinking skills. Data was collected from digital learning resources created in H5P and paper-based artifacts presenting students' written solutions. We extracted xAPI statements from these H5P tasks to capture students' interactions with the digital learning resources. Custom scripts were developed to retrieve data from Learning Locker, enabling the extraction and analysis of xAPI statements produced during student engagement with the tasks. Each student result was evaluated based on two criteria: artefact improvement (if the student improved the artefact after collaboration or not) and solutions proposed after collaboration based on Docktor's rubric (max 3 points). Students explained their artefact, influenced the grading in their MAPS rubric. For example, a student who was weak in explaining how light travels, but constructed the sketch correctly, gets a high score in "Specific Physics Application", but less in "Useful description" MAPS categories. Based on students' problem-solving strategies, we identified three distinct student profiles using hierarchical cluster analysis and K-means clustering analysis with three predetermined clusters as a reference. In addition to the Expert-Novice categorization from Docktor's (2016) [29] rubric, we identified a third profile, termed "Struggling," characterized by relatively low scores across all complex problem-solving dimensions. Our results suggest that as cognitive demands increased, students in the 'Expert' cluster, who had higher domain knowledge and better problem-solving strategies, performed better even without support. In contrast, other groups required additional scaffolding, likely of a different type. In the future, we need to validate these scaffolding strategies in longer interventions. Based on this validation, we can design a feedback loop where students can indicate confusion, allowing teachers to adjust the dynamically level of support provided. This approach ensures that scaffolding is not only supportive but evolves with the student's learning processes, helping teachers make better decisions for differentiated instruction tailored to different profiles of problem-solvers.

5. Contributions

My PhD research aims to address the gap in teachers' ability to design and implement effective teaching strategies that cater to the varying problem-solving abilities of students, particularly through the integration of learning technologies. First, my research contributes by demonstrating alignment between pedagogical models and computational models in the context of adaptive scaffolding. This research provides insights into how educational theories can be integrated with data-driven approaches to enhance students' problem-solving skills in the technology-enhanced learning environment. To be more precise, then the plan is to employ cluster analysis and other data-driven techniques to analyze student interaction data, enabling the identification of learning patterns and problem-solving abilities without solely relying on traditional assessments. Second, my research contributes to the development of adaptive scaffolding strategies that can dynamically support students based on their problem-solving needs. By proposing a model-based LA approach, this research offers methods to design interventions and support mechanisms in real-time. For teachers, to implement adaptive scaffolding strategies that are specifically tailored to distinct student problem-solving profiles—namely, Expert, Novice, and Struggling learners—to enhance their problem-solving skills effectively. Furthermore these scaffolding strategies address both cognitive processes (e.g., problem-solving steps, conceptual understanding) and metacognitive skills (e.g., self-regulation, reflection) to support comprehensive skill development. Third, my research enables a better understanding of teachers' awareness and decision-making processes through model-based LA. Providing teachers with actionable insights derived from student data and pedagogical models helps them make informed instructional decisions that foster student problem-solving skills. This requires the active involvement of teachers in co-designing technological tools and providing ongoing professional development to enhance their data literacy and capacity to implement adaptive scaffolding. These goals are ultimately achieved by employing DBR to derive and validate design principles, outlining best practices for integrating computational models with pedagogical theories, and designing teacher dashboards.

References

[1] OECD, PISA for development mathematics framework, in: PISA for Development Assessment and Analytical Framework: Reading, Mathematics and Science, OECD Publishing, Paris, 2018.
[2] B. Kramarski, I. Weiss, S. Sharon, Generic versus context-specific prompts for supporting self-regulation in mathematical problem solving among students with low or high prior knowledge, Journal of Cognitive Education and Psychology 12 (2013) 197–214.
[3] J. Sweller, R. E. Clark, P. A. Kirschner, Teaching general problem-solving skills is not a substitute for, or a viable addition to, teaching mathematics, Notices of the American Mathematical Society 57 (2010) 1303–1304.
[4] B. Kramarski, S. Friedman, Solicited versus unsolicited metacognitive prompts for fostering mathematical problem solving using multimedia, Journal of Educational Computing Research 50 (2014) 285–314.
[5] OECD, TALIS 2018: Insights and Interpretations, OECD Publishing, Paris, 2019.
[6] F. Pettersson, On the issues of digital competence in educational contexts—a review of literature, Education and Information Technologies 23 (2018) 1005–1021.
[7] M. Bond, S. Bedenlier, Facilitating student engagement through educational technology: towards a conceptual framework, Journal of Interactive Media in Education 2019 (2019) 11.
[8] A. A. Genlott, Å. Grönlund, Closing the gaps—improving literacy and mathematics by ICT-enhanced collaboration, Computers & Education 99 (2016) 68–80.
[9] H. Crompton, D. Burke, Y.-C. Lin, Mobile learning and student cognition: A systematic review of PK–12 research using Bloom's taxonomy, British Journal of Educational Technology 50 (2019) 684–701.
[10] B. J. Reiser, I. Tabak, Scaffolding, in: R. K. Sawyer (Ed.), The Cambridge Handbook of the Learning Sciences, Cambridge University Press, 2014, pp. 44–62. doi:10.1017/CBO9781139519526.005.
[11] K. Tammets, M. Khulbe, L. H. Sillat, T. Ley, A digital learning ecosystem to scaffold teachers' learning, IEEE Transactions on Learning Technologies 15 (2022) 620–633.
[12] D. Gašević, S. Dawson, G. Siemens, Let's not forget: Learning analytics are about learning, TechTrends 59 (2015) 64–71.
[13] A. F. Wise, D. W. Shaffer, Why theory matters more than ever in the age of big data, Journal of Learning Analytics 2 (2015) 5–13.
[14] I. Molenaar, A. Horvers, R. Baker, Towards hybrid human-system regulation: understanding children's SRL support needs in blended classrooms, in: Proceedings of the 9th International Conference on Learning Analytics & Knowledge, ACM, 2019, pp. 471–480.
[15] M. Khulbe, K. Tammets, Mediating teacher professional learning with a learning analytics dashboard and training intervention, Technology, Knowledge and Learning 28 (2023) 981–998.
[16] T. Ley, K. Tammets, E. M. Sarmiento-Márquez, J. Leoste, M. Hallik, K. Poom-Valickis, Adopting technology in schools: modelling, measuring and supporting knowledge appropriation, European Journal of Teacher Education 45 (2022) 548–571.
[17] V. Aleven, E. A. McLaughlin, R. A. Glenn, K. R. Koedinger, Instruction based on adaptive learning technologies, in: R. E. Mayer, P. A. Alexander (Eds.), Handbook of Research on Learning and Instruction, Routledge, 2016, pp. 522–560.
[18] A. Fischer, S. Greiff, J. Funke, The process of solving complex problems, Journal of Problem Solving 4 (2012) 19–42.
[19] K. Holstein, B. M. McLaren, V. Aleven, Intelligent tutors as teachers' aides: exploring teacher needs for real-time analytics in blended classrooms, in: Proceedings of the Seventh International Learning Analytics & Knowledge Conference, ACM, 2017, pp. 257–266.
[20] S. Shanta, J. Wells, T/E design based learning: assessing student critical thinking and problem solving abilities, International Journal of Technology and Design Education 32 (2022) 267–285.
[21] F. Liu, L. Zhao, J. Zhao, Q. Dai, C. Fan, J. Shen, Educational process mining for discovering students' problem-solving ability in computer programming education, IEEE Transactions on Learning Technologies 15 (2022) 709–719.
[22] R. Baker, J. Clarke-Midura, J. Ocumpaugh, Towards general models of effective science inquiry in virtual performance assessments, Journal of Computer Assisted Learning 32 (2016) 267–280.
[23] M. C. Kim, M. Hannafin, Scaffolding problem solving in technology-enhanced learning environments (TELEs): Bridging research and theory with practice, Computers & Education 56 (2011) 403–417.
[24] C. Romero, S. Ventura, Educational data mining and learning analytics: An updated survey, Wiley Interdisciplinary Reviews: Data Mining and Knowledge Discovery 10 (2020) e1355.
[25] E. V. Frolova, O. V. Rogach, T. M. Ryabova, Digitalization of education in modern scientific discourse: new trends and risks analysis, European Journal of Contemporary Education 9 (2020) 313–336.
[26] T. Ley, K. Tammets, G. Pishtari, P. Chejara, R. Kasepalu, M. Khalil, M. Saar, I. Tuvi, T. Väljataga, B. Wasson, Towards a partnership of teachers and intelligent learning technology: A systematic literature review of model-based learning analytics, Journal of Computer Assisted Learning 39 (2023) 1397–1417.
[27] J. Henderson, M. Corry, Data literacy training and use for educational professionals, Journal of Research in

Innovative Teaching & Learning 14 (2021) 232–244.
[28] F. Wang, M. J. Hannafin, Design-based research and technology-enhanced learning environments, Educational Technology Research and Development 53 (2005) 5–23.
[29] J. L. Docktor, J. Dornfeld, E. Frodermann, K. Heller, L. Hsu, K. A. Jackson, A. Mason, Q. X. Ryan, J. Yang, Assessing student written problem solutions: A problem-solving rubric with application to introductory physics, Physical Review Physics Education Research 12 (2016) 010130.
[30] M. Goos, P. Galbraith, P. Renshaw, A money problem: A source of insight into problem solving action, International Journal for Mathematics Teaching and Learning (2000) 1–21.