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Learning Analytics: A Case Study on Exploring Social Interaction and Problem-Solving Strategies

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Purpose: The purpose of this study is to preliminarily verify the concept of personalised and collaborative learning and to formatively observe students' knowledge, skills, problem-solving strategies and social dynamics in the classroom.

Study design/methodology/approach: The study was conducted with 8th grade students (N=21) using the ClassRoom Analytica (CRA) application as part of a thematic unit on ionic bonds. Students participated in digitally facilitated group problem-solving activities guided by predefined parameters for accessing information.

Findings: The use of the CRA application proved highly beneficial in a heterogeneous class as it was responsive to all students and provided the teacher with detailed information about each individual's role within the class.

Originality/value: This study presents CRA as a novel integration of learning analytics and domain-specific visualisations in the science classroom.

Introduction

With the development of information technology, the volume of variably accessible information is rapidly increasing, impacting teaching methods or processes. Social, technical, and multimedia development are transforming learning environments, thereby dictating changes in the learning process. Learning is increasingly tailored to the individual, with self-organization processes playing an important role. Given the numerous ways to acquire information, learners are increasingly shaping their own learning process in their pursuit of rapid knowledge acquisition. Thus, learners play an active role in creating their learning process, while teachers are evolving into mentors who guide them. Learning is also becoming more collaborative, with social platforms enabling interaction and collaboration at various levels (Wallace, 2014; Cerda & Planas, 2011).

Learning is no longer limited to the traditional student-teacher interactions within educational institutions. Home-based learning is also gaining a more significant role, providing a foundation for more creative engagement with schoolwork, which is now more focused on problem-solving. This shift is leading to the rise of collaborative and flipped learning models, whose growing prevalence in practice demonstrates significant advantages (Wallace, 2014; Cerda & Planas, 2011; Petrović et al., 2013; Bishop & Verlager, 2013; Du, et al., 2014). Johnson et al. (2000) demonstrated that various collaborative methods, when used correctly, have a significant positive impact on student achievement. From a psychological perspective, intrinsic motivation increases, contributing to greater activity and perseverance among students in problem-solving. Collaborative work also enhances the speed of information transfer and the quality of knowledge among participants.

In modern educational systems, there is an increasing emphasis on improving students' learning through the use of formative assessment (Black & Wiliam, 2009; Wylie, 2020). Formative assessment focuses on learning objectives and students' progress, guiding them on what they need to do to achieve these goals and providing specific feedback to enhance their learning or improve their knowledge. Consequently, the results of formative assessment can help teachers document individual students' learning progress, identify those who require additional learning support, and appropriately adjust the learning process. Experimental studies (Lehmann et al., 2014; Spector et al., 2016) indicate that formative monitoring and targeted, ongoing feedback to students encourage positive activities in online environments (Tempelaar et al., 2013) and are among the strongest factors for improving students' learning approaches and experiences. This is primarily because formative assessment is tailored to adapt the learning approach to the actual abilities and needs of each individual student.

Adapting the learning process to individual students requires teachers to gather as much information as possible about each student's learning specifics. Computer-supported learning analytics play an important role in this regard, providing teachers with digital insights into various segments of the learning process, as well as students' characteristics and responses. The primary goal of learning analytics is "to leverage data obtained in educational environments to optimize learning and the environment in which it occurs" (Nouri et al., 2019). Ifenthaler and Schumacher (2016) state that learning analytics encompasses information about: (1) individual student characteristics (e.g., prior knowledge, learning performance), (2) student activities in the learning environment (e.g., paths, forms, organization of work on specific tasks), (3) curriculum performance criteria (e.g., learning achievements, schooling data), and (4) interactions with peers and teachers (e.g., activity on social networks). Tailored learning analytics are increasingly sought after and valued in educational institutions. They are used to create a customized learning process optimized for each individual student, based on their personal profile. In our case study, this profile included information on learner's problem-solving strategies with a focus on social interactions.

The purpose of this study is to preliminarily verify the concept of personalized and collaborative learning and to formatively observe students' knowledge, skills, problem-solving strategies, and social dynamics in the classroom. We have developed this concept and implemented it in the Learning Analytics application, which we will briefly introduce in the next chapter.

ClassRoom Analytica (CRA): Testing Phase Insights

Personalizing the learning process presents new challenges in the field of education. Adapting learning processes to individuals requires teachers to gather numerous data about each student's learning specifics, such as information sources, social interactions, and problem-solving strategies. Since acquiring and analysing this information poses a challenge for teachers, learning analytics plays a crucial role in enabling data acquisition, analysis, and visualization. A review of existing applications in this field has revealed numerous options (such as Adeptimy, Knewton, Cerego, Domoscio, etc.) that facilitate personalized problem-solving based on students' knowledge and knowledge progression. These applications link content to curriculum schemes, providing students with precise insights into their knowledge gaps. Teachers gain real-time insight into students' work, while students receive feedback on their progress. However, the review of applications also uncovered shortcomings, particularly in addressing social interactions and the ability to select different information sources. These shortcomings motivated the development of a new application, which we named ClassRoom Analytica (CRA).

The CRA application encompasses key aspects of learning analytics aimed at enhancing the personalization of the learning process. The teacher's workspace allows for the creation of problem tasks, the preparation of teaching materials, and the ability to gain insights through data analysis and visualization. Data analysis and visualization within the application are divided into three levels.

-Individual Problem-Solving: Visualization of data from the perspective of solving individual problems.

- Social Interactions: Visualization from the perspective of social interactions within the group.

- Problem-Solving Strategies: Visualization of each student's problem-solving strategy.

Based on collected data and built-in methods of learning analytics, the application enables data visualization from the perspective of solving individual problems, from the perspective of social interactions within the group, and from the perspective of each student's problem-solving strategy. The application provides a precise insight into each student's problem-solving process or strategy (e.g., independent work, trust in knowledge, information search, copying, etc.), enabling the so-called profiling of students based on their characteristics. Special attention is given to various information sources (teacher's materials, social interactions among students, group statistical results, web), which provide students with the opportunity for self-organization in the pursuit of successful and faster problem-solving. This distinguishes our application from existing ones on the market, with a special emphasis on enabling collaboration among students and revealing social interactions within the group.

The application is currently available only in Slovenian and is still in the process of development. As described in this article, we are testing it through pilot projects to gather guidelines for further application development. Our goal is to achieve a more autonomous personalization of the learning process.

Case Study in Chemistry

The case study evaluates the effectiveness of the CRA application in the 8th grade primary school Chemistry education (13-14 years of age). Chemical concepts and phenomena are inherently abstract, presenting challenges for many students. Teaching chemical content is complex due to the triple nature of chemical concepts (macroscopic, symbolic, and submicroscopic), which are used to describe and explain chemical phenomena (Rizman Herga et al., 2015). To address these challenges, science education employs various visualization methods across all levels, alongside stationary models. These methods use computer-generated models of substance components in 2D or 3D formats, both static or dynamic, to bridge the description of macroscopic changes with the submicroscopic level and to illustrate the particulate nature of substance structure. The integration of ICT with various tools for visualization, simulations, applications, virtual laboratories, and platforms enhances students' understanding of chemical concepts and processes.

To implement the CRA application in school settings, we have created and tested various teaching materials. Table 1 highlights some of these materials, specifically developed for learning and teaching chemistry, providing a comprehensive approach. These materials include the preparation of teaching content, lesson delivery, student assessment using the CRA application, and analysis of results using teaching analytics provided by the CRA application.

Table 1. Development of materials for testing the CRA application in chemistry classes (students aged 13-14)

Thematic clusters	Content
Chemistry is the world of substances	Elements and compounds
Atom and the periodic table of elements	Structure of the atom
Connecting particles/components	Ionic bonding and substance properties

To conduct the lessons, we created a comprehensive outline of learning objectives and detailed lesson plans for teachers. We focused on problem-solving tasks designed to assess students' understanding using the CRA application. The aim was to collect extensive data on students' problem-solving strategies and their social interactions within the classroom. During the lessons, we structured tasks based on thematic clusters that highlight the submicroscopic nature of chemical concepts, essential for comprehension. We used a variety of test and quiz scenarios, each with different variables. The same student group used the CRA application multiple times. Its usage proved beneficial in reinforcing the learning material, providing teachers with rapid feedback on the student's understanding of the covered topics.

Results of using the CRA application in teaching and learning content related to ionic bonding

This case study introduces the concept of learning analytics with CRA, by highlighting the use of learning analytics and potential outcomes of the CRA application rather than detailing the specific classroom research. The conducted research aimed at determining:

- The effectiveness of students' problem-solving skills when using the CRA;
- Each student's problem-solving strategy, including their approach (whether they solved tasks sequentially or based on difficulty), and the information sources they used for solving a specific problem;
- The social dynamics among students within a specific group during problem-solving activities. This includes whether students connect with each other, who they seek help from when needed, whether connections are formed based on gender, who is perceived as a primary or reliable source of information, if multiple such sources in the group exist, whether there are individualists in the group who rely solely on their own judgment, etc.

The study included a population of students (N = 24) attending the 8th grade during the 2021/22 school year (ages 13-14). Although the students were evenly distributed by gender, the class exhibited considerable heterogeneity in learning abilities. The class demonstrated significant success in mastering chemistry learning standards, with over half of the students (N = 14, 58.3%) achieving higher knowledge standards. The selected student group represents a simple random sample from a hypothetical population. Data collection was conducted through a quiz designed for our research objectives. We ensured the quiz's content validity through rational validation. The quiz, administered in January 2022, consisted of 12 questions (each worth 1 point), covering 12 concepts (Table 2). Detailed instructions were provided to maintain objectivity. The application of the CRA facilitated the evaluation, visualization of results, and student profiling.

Empirical data were collected from the 8th grade students during Chemistry class, explicitly focusing on the thematic cluster of Particle Connection. This cluster included the teaching unit on Ionic Bonding, where students acquired information independently. All quiz questions were multiple-choice, allowing the tracking of individual student responses. Before students attempted the questions, the teacher outlined the available information sources (response statistics, supplementary texts, web resources, classmate's response, etc.).

Table 2. Concept covered in the quiz

Question	Concept
1	ionic compound
2	property and structure of matter
3	ions
4	ionic crystal
5	formula unit
6	ionic compound
7	ionic compound
8	ionic compound and formula
9	ionic compound and nomenclature
10	cations and anions
11	ionic bond
12	building blocks of matter

The results are presented in the following three sections: Analysis of a class group, Analysis of group social dynamics, and an Example of applying the results for profiling students in the class.

a) Analysis of a class group

In terms of data visualization, the teacher can access an analysis of the overall quiz results for the entire class as a group (Figure 1). 21 students participated in the quiz, with 3 students absent (N = 21). On average, students scored 6 points out of 12 (50%). The highest number of students (N = 9) achieved 70% of the possible points. On average, the group of students spent 14 minutes completing the quiz. The average time per question decreased from the first to the last question.

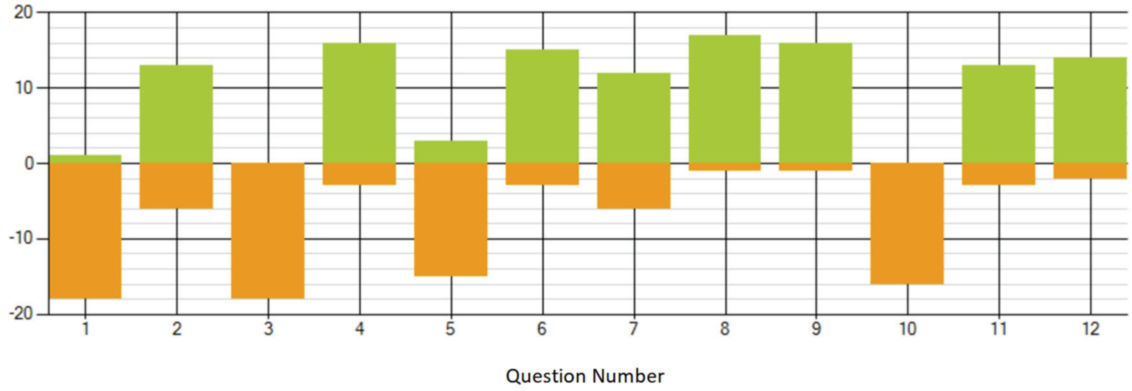

Figure 1. Success rate in solving the quiz (green: correct answers, orange: incorrect).

As students tackled the quiz alongside their exploration of new course material, the CRA application provided them with access to various aids, including representations of ions, the explanations of ionic bond formation, substance descriptions, teacher assistance, and an instructional video guide. Additionally, students could opt to work on extra exercises, watch educational videos, or complete quizzes prepared by the teacher. Figure 2 illustrates the frequency of events for each question, with question 5 receiving the highest number of events, and question 9 the lowest. Students primarily constructed their learning process by seeking information sources, often consulting answer statistics and classmates' responses after making their answer selections. They also used supplementary texts provided by the teacher or sought further information through the teacher-prepared materials and the resources available on the World Wide Web.

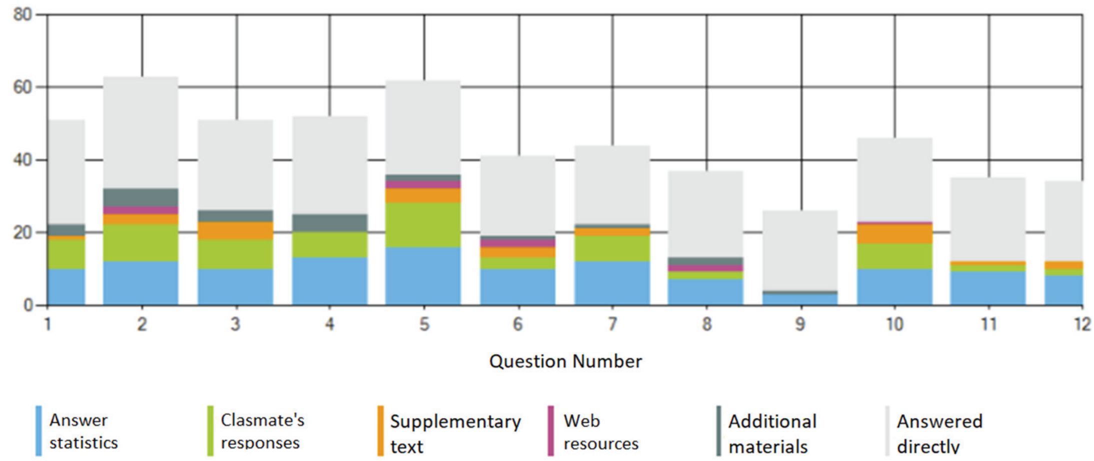

Figure 2. The frequency of events for questions 1-12. The events pertain to: Answer statistics, Classmate's responses, Supplementary text, Web resources, Additional materials, and the student's direct answer.

b) Analysis of group social dynamics

Analysis of the group's social dynamics revealed that students used the CRA application to acquire and cross-check information, facilitating mutual connections (Figure 3). Two students stood out in terms of incoming connections (as expected, due to their excellence in chemistry and high knowledge standards. However, it is surprising that their number is not higher. In the class, five students did not collaborate with others when solving problems. When acquiring new information or verifying their solutions, students tend to focus less on everyday friendships and more on their classmates' knowledge, performance, and success in the subject area.

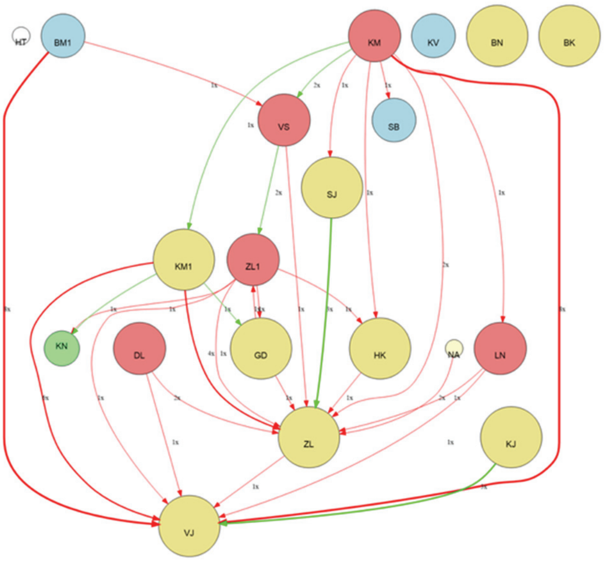

Figure 3. Visualization of social interactions. The number next to each arrow represents how many times a particular student viewed the results of another student in the group. The size of the circles indicates the performance of each student in solving the test.

c) Example of applying the results for profiling students in the class

Comparative analyses of academically successful students with the entire class (Figure 4) reveal that this group is more diverse than initially assumed. Student BM stands out with numerous outgoing connections. Despite being one of the most successful students in chemistry, student BM appeared less confident in problem-solving. In contrast, In contrast, student HK achieved higher success than most classmates but needed to engage in more activities than average to solve problems. Student VJ had the highest number of incoming connections, indicating that many peers sought help from VJ. Their time expenditure and success rates were above average. Similarly, ZL achieved above average success with many incoming connections but showed minimal activity and time expenditure. Interestingly, among the seven academically successful chemistry students, most sought guidance from only two peers, with student VJ being the most frequently approached for insights.

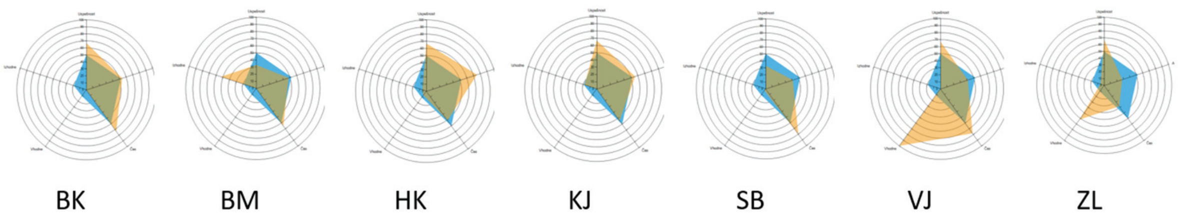

Figure 4. Comparative analysis of individuals (orange) with the group (blue). Clockwise from the top: Succes rate, Activity, Time used for solving the quiz, Incoming connections, Outgoing connections. BK, BM, etc., are the initials of students' names.

Discussion and conclusions

To help students grasp abstract chemical concepts, we designed problem questions focusing on particle interactions (within the learning unit on Ionic Bonding). The use of the CRA application proved highly beneficial in heterogeneous class, as it caters to all students and provides the teacher with detailed information on each individual's role within the class. Another noteworthy aspect of CRA is its capacity for individualization. Teachers can integrate diverse content and activities when creating supplementary materials, thereby ensuring personalized learning experiences, and assessing students' comprehension of chemical concepts.

Visual aids play a crucial role in teaching and learning chemical content by offering effective external visual representations of ideas and phenomena. These aids help students develop mental models, enhancing their learning outcomes. They include various visualization elements (macro, submicro (2D or 3D), and symbolic components of the content being studied), which facilitate the cognitive process of acquiring new chemical concepts. Before engaging in problem-solving activities, the teacher sets the parameters for using various sources of information (response statistics, supplementary text, internet resources, peer responses, etc.). The material was developed as part of the Particle Interactions thematic unit in the 8th-grade Chemistry curriculum.

The study aimed to identify correlations between problem difficulty, problem-solving success rate, solving time, and problem-solving strategies. Additionally, we investigated the social dynamics within a specific student group, particularly examining how these dynamics during problem-solving related to the classroom sociogram. Furthermore, we analysed social interactions among students with varying levels of knowledge. The study successfully verified our concept of personalized and collaborative learning by observing students' knowledge, skills, problem-solving strategies, and social interactions in the classroom. These insights were pivotal in shaping our understanding of effective practices.

Building on these findings, our next steps involve finalizing the production version of the CRA application. This tool aims to support personalized learning experiences and enhance collaborative problem-solving among students. We plan to launch the CRA application in the market, making it accessible to educational institutions seeking innovative solutions to foster student engagement and academic success.

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