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Good teaching practices on the example of chemistry teaching in non-chemistry studies

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Abstract

The article examines the primary pedagogical challenges currently encountered by university educators and explores selected instructional methods that can enhance the quality of education. It outlines specific strategies and interventions designed to increase student engagement during classes, with a particular focus on the case study involving Chemistry lectures for Sanitary Engineering students in the Environmental Engineering program within civil construction. The positive outcomes, both in terms of activating student participation and improving learning efficiency, were corroborated over several years of observation. The findings demonstrate that, with an appropriate pedagogical approach, it is possible not only to impart knowledge but also to foster engagement, motivation, and positive relationships that contribute to the holistic development of students. The article highlights the importance of continuous improving of educators' teaching competencies and adapting curricula and instructional methods in order to meet the rapidly evolving demands of the labour market.

Keywords

teaching, higher education, activating methods, chemistry

Dobre praktyki dydaktyczne na przykładzie dydaktyki chemii na studiach niechemicznych

Abstrakt

W artykule przeanalizowano główne problemy dydaktyczne, z jakimi borykają się obecnie dydaktycy na uczelniach wyższych, a także omówiono wybrane metody dydaktyczne, które mogą przyczynić się do poprawy jakości kształcenia. Opisano konkretne strategie i działania podejmowane w celu zwiększania zaangażowania studentów podczas zajęć na przykładzie wykładu z Chemii Sanitarnej prowadzonego dla studentów kierunku Inżynieria środowiska w budownictwie. Pozytywne efekty zarówno w aktywizacji słuchaczy, jak i we wzroście efektywności przyswajania przez nich wiedzy potwierdzono kilkuletnimi obserwacjami. Udowodniono, że dzięki odpowiedniemu podejściu można nie tylko przekazywać wiedzę, ale także budować zaangażowanie, motywację i pozytywne relacje, które wspierają ogólny rozwój studentów. Podkreślono potrzebę ciągłego doskonalenia kompetencji dydaktycznych nauczycieli oraz adaptacji programów i metod nauczania do dynamicznie zmieniających się potrzeb rynku pracy.

Słowa kluczowe

dydaktyka, szkolnictwo wyższe, metody aktywizujące, chemia

1. Introduction

According to The Framework for 21st Century Learning, developed by The Partnership for 21st Century Learning, we should now vigorously pursue a paradigm shift from school-centred education to student-centred education (The Partnership for 21st

Century Learning, 2019). The contemporary teaching process at universities has evolved significantly compared to the period when many current lecturers received their own training. The rapidly changing world, the dynamic advancement of technology, the increasing demands of the labour market, and the changing student expectations require universities to adapt to these new realities. Consequently, achieving a balance that satisfies both parties involved in the educational process – students and educators – often proves challenging. To this end, it is essential to promote and implement educational policies and practices based on innovative teaching methods that support the development of competencies that ensure that students meet the challenges of the 21st century. The Framework defines the skills, knowledge, experiences, and support systems that students need today to succeed in work, private life, and civic engagement. Key skills include a broad set of competencies, including creativity, communication, collaboration, entrepreneurship, soft skills and critical thinking.

Many researchers (Qi 2024; Arsyad 2024: 2) emphasize the key role of developing critical thinking skills in chemistry didactics for success and innovation in many sectors where chemical knowledge is essential (pharmacy, environmental sciences). In the Polish higher educational system, traditionally, the main form of teaching is the lecture and students usually adopt a passive stance during it, both physically and cognitively. Namely, this form of teaching is economical in terms of cost and time, as it can be used to teach a large number of students simultaneously. However, it does not provide a basis for active engagement of students in the learning process. Students passively take notes, often without being allowed to interrupt the lecturer to clarify issues they do not understand.

The article presents a number of practices developed to meet the above-mentioned challenges to ensure the quality of education and efficiency of the lecture. The project concerns lectures on *Chemistry for Sanitary Engineering* delivered to students in the first semester of the course *Environmental Engineering in Civil Construction*. For years the failure to pass this subject has

seemed to be one of the significant reasons for the drop-out phenomenon among the first-year students. The following techniques and methods are designed to enhance students' engagement in the acquisition of chemical knowledge, increase learning efficiency, and, consequently, improve academic performance and success rates in the subject. Furthermore, these approaches aim to inspire students to continue studies in the field.

2. How it all started: Good and poor learner studies

Effective teaching practices are essential for fostering successful learning outcomes. Outlined below are the foundational principles essential for consideration when efforts to enhance the educational process in the 21st century are taken into account (Khahro 2022: 14; Rahman 2022: 17).

Without any doubt, there are clear and understandable learning objectives and contextualization of learning that shall start the discussion about good practices. Namely, an increasing number of young individuals are prioritizing the acquisition of skills and competencies that will obviously have direct relevance to their future careers or daily lives. This pragmatic approach is understandable in a rapidly developing world, where time and resources are limited, and employment prospects are contingent upon specific skill sets rather than solely on the credentials of a diploma. Consequently, as Sewagegn (2020: 8) points out, it is essential within the teaching process to clearly articulate learning objectives both at the outset of a course and prior to the introduction of each new topic. Students should be aware of the expected outcomes and what they are expected to achieve by the end of the course. Furthermore, the realization of these objectives should be measurable and attainable, enabling students to effectively track their progress and engage in self-assessment.

Moreover, lecturers should consistently emphasize how the material being discussed can be applied in various professional and everyday contexts. Demonstrating the practical relevance of

theoretical concepts enhances students' engagement and motivation to learn. Students, in particular, show significant interest in working on real-world problems through case studies, as this allows them to observe the practical implementation of theoretical knowledge. Such an approach not only aids in their understanding of the subject matter but also underscores the importance and relevance of the material being taught.

Additionally, promoting a holistic approach, namely, balancing pragmatism with general knowledge plays a crucial role in the educational process of the university students. While students may tend to focus on acquiring knowledge, they consider immediately relevant, it is essential at the university level also to promote a well-rounded education that fosters development within a broader social, cultural, and ethical framework. Thus, when maintaining an emphasis on pragmatism, it is equally important to highlight the potential long-term benefits of broad knowledge and diverse skills, which can unexpectedly advance both their careers and personal lives by enabling them to better comprehend the world and make informed decisions. In this context, incorporating personal anecdotes and experiences, commonly referred to as "storytelling," proves particularly effective in conveying these broader educational values.

Another issue that has its enormous significance for the educational process is the use of modern technology. Today's young generation, having grown up in the digital age, naturally enters higher education with the expectation of having digital technologies included into the teaching process. However, research has shown that this expectation often encounters resistance from teaching staff, reluctant to adopt new instructional methods (Anis 2024: 6). Many lecturers continue to value only traditional teaching approaches, such as lectures that primarily focus on the transmission of theoretical knowledge. Moreover, educators who were themselves taught by the use of more conventional methods frequently struggle to accept that these "older" teaching techniques may no longer appeal to the contemporary students or achieve similar positive outcomes. In conversations with experienced educators, one often hears

criticisms of modern, more active teaching methods, which are sometimes dismissed as “childish,” “primitive,” or simply “a waste of time.”

Moreover, lecturers who have used traditional forms of instruction for many years may face considerable challenges in adapting to the evolving educational landscape. Namely, their resistance can stem from a variety of factors, including insufficient digital literacy, fear of change, or an ingrained preference for familiar methods. In order to facilitate the successful implementation of contemporary teaching approaches, it is crucial to offer instructors adequate support, training, and incentives to embrace innovation in their teaching practices. However, one critical barrier to this transition is the lack of time, which is often in short supply.

In disciplines such as chemistry, the use of modern technological tools, including 3D visualizations, mobile applications, and interactive learning programs, can significantly improve students' comprehension of complex topics and foster their creative thinking. For example, apps that simulate chemical reactions enable students not only to observe interactions between substances but also to analyse the outcomes in real-time. Additionally, remote laboratories and computer simulations can greatly enrich the learning experience while simultaneously reducing educational costs. These advancements demonstrate the potential of digital technologies to transform traditional learning environments into more dynamic, engaging, and cost-effective educational settings.

Marchak et al. (2021: 98) have shown that also in chemistry didactics it is possible to make effective use of all the AI possibilities and online teaching tools while maintaining pedagogical diversity and flexibility, and offering creative and active strategies for learning chemistry, at the same time maintaining social relationships between students and teachers. According to Dingel et al. (2023), strong relationships with students are fundamental to an effective teaching process. It is essential to make an effort to understand an individual student and foster a rapport based on mutual respect, as this can significantly enhance

their engagement and motivation to learn. An empathetic approach is crucial in this regard – being open to students' perspectives and concerns, while offering understanding and support, can contribute positively to their academic experience. It is also important to remain aware of the fact that students may face a range of academic and personal challenges, which can affect their performance and overall well-being.

However, the process of cultivating positive relationships extends beyond the dynamic between the lecturer and students; equally important are the interactions among students within a group. The author's experience suggests that a cohesive group functions more effectively, if there are students who participated in team-building activities during their initial classes in the first year of study often achieving higher academic performance across various subjects in subsequent years, compared to those who began their studies through conventional methods. This observation is further corroborated by student feedback collected through surveys, which consistently highlights the benefits of early group cohesion for a long-term academic success.

As follows, a fundamental prerequisite for fostering students' openness to learning is the creation of a supportive and welcoming atmosphere in the classroom. Without any doubt, fear can inhibit cognitive function and hinder the learning process. Ideally, then, the classroom environment should encourage students to feel comfortable asking questions and expressing their opinions, even if those contributions may be factually incorrect. Furthermore, it is equally crucial to ensure that certain negative behaviours – such as judgment, criticism, sarcasm, ridicule, labelling, and dismissal – are avoided in interactions with students. This necessitates careful attention to both the content and manner of communication, as well as ongoing efforts to ensure that the message is correctly interpreted by the students.

It must be pointed out that effective communication is crucial for fostering positive relationships with students and plays an essential role in the teaching and learning process. Moreover, it is important to be clear and precise when communicating with students, particularly when addressing complex topics or pro-

viding task instructions. One can do it by means of simplifying explanations, and avoiding unnecessary complications is the key. Additionally, employing real-life examples, analogies, and visual aids, as previously mentioned, often yields positive results.

To ensure effective communication with students, it is advisable to establish clear communication channels, such as email, educational platforms, or in-person and virtual meetings, along with clearly defined consultation hours. Furthermore, it is imperative to provide timely responses to student inquiries, ideally within 24 to 48 hours. Such promptness not only reflects the lecturer's commitment and professionalism but also indicates sensitivity to student needs, thereby inspiring respect and strengthening the student-lecturer relationship.

Treating students with respect is a fundamental aspect of building positive relationships, it warrants good atmosphere conducive to learning in the current educational climate. In the 20th century, academic practice predominantly required respect to be shown unilaterally, with students being expected to show respect towards their teachers. However, contemporary standards demand that respect be reciprocated equally between students and educators. To effectively show respect towards students, educators should engage in practices such as soliciting students' opinions on relevant topics, attentively listening to their contributions, requesting clarification of or elaboration on where necessary, and providing constructive feedback.

The current generation of young adults exhibits a different perspective on the external world, interpersonal relationships, and their expectations of educational environments. A decade ago, incorporating humour related to course content into lectures often produced positive outcomes. However, in recent years, there has been an increasing trend when students not only fail to appreciate previously effective jokes but also perceive them as inappropriate or even personally offensive, as reflected in the feedback from class surveys. Therefore, when opting to include humour in the classroom, it is crucial to exercise careful judgment and sensitivity to the context.

Additionally, it is considered a good practice to solicit student feedback regarding the effectiveness of the classes. This can be achieved through surveys, brief questions at the end of class, or direct conversations. Such feedback provides valuable insights, enabling continuous improvement in teaching methods and communication approaches.

An essential component of effective communication with students involves providing timely and constructive feedback. It is advisable to regularly inform students of their progress through mechanisms such as interim grades, written comments on assignments, or progress reports. This practice enables students to monitor their advancement towards achieving their educational objectives. Simultaneously, fostering self-reflection – an important skill that many contemporary students lack – should be encouraged. According to Carless et al. (2020: 28), supporting students in self-assessment of their performance and identifying areas for improvement is crucial in developing this competency.

In numerous instances, it is essential to offer individualized support to students, either in terms of academic content or in the area of personal development. Whenever feasible, universities should aim to provide students with access to mentors who can assist them in identifying the skills and knowledge most beneficial for their future careers. This personalized learning approach enables students to concentrate on key areas critical to shaping their individual career paths and achieving their goals (Ghulam 2024:1).

Furthermore, in individual face-to-face consultations, it is crucial to personalize communication, ensuring that the mode of interaction is tailored to the specific needs of each student. In this context, flexibility and openness to adjustments are particularly valuable. By adopting these strategies, educational institutions can effectively meet the diverse needs of students, thereby providing comprehensive and meaningful education that equips them not only for their initial employment but also for a long-term career success and life in the changing world.

3. Educational project

The primary aim of the project under discussion was to enhance and address the modern pedagogical challenges associated with the lectures on *Chemistry for Sanitary Engineering*, delivered during the first semester of the *Environmental Engineering in Civil Construction* program. Observations were conducted over four academic years, from October 2020 to June 2024. However, data from the 2020/2021 academic year were excluded from the study, as the course was predominantly delivered online, and student behaviour during this period was deemed unrepresentative of typical classroom dynamics. The study involved groups ranging from 20 to 40 students. Despite the lecture format, both theoretical concepts and practical tasks, including test problems and equation solving, were integrated into the sessions.

The key teaching challenges encountered in the project are discussed below, along with the methods that were introduced to address them:

1. a significant variation in the level of students' prior knowledge;
2. the absence of student motivation, coupled with the inability to contextualize the subject within its broader disciplinary framework and to relate it to other subjects in the core curriculum;
3. the lack of student involvement during lectures;
4. the lack of critical thinking skills;
6. the lack of time to absorb or repeat material at home.

3.1. A significant variation in the level of students' prior knowledge

A significant number of students entering higher education are insufficiently prepared for its academic demands, which often leads to learning difficulties and increased dropout rates. In the

field of study under examination, there is a notable disparity between high school graduates from biologically and chemically focused curricula, and technical school graduates with specializations in geodesy or renewable energy. The former group possesses a substantial foundation in chemistry, covering much of the material included in the course, whereas the latter may struggle to recall even basic chemical symbols. This wide variation in students' prior knowledge presents a considerable challenge for the lecturer. The primary question is how to make the subject matter accessible to students who arrive with minimal chemistry background, while simultaneously ensuring that those who have completed advanced chemistry courses, such as the baccalaureate exam, are neither disengaged nor bored.

To address this disparity, the project implemented several techniques aimed at individualizing instruction, thereby adapting the educational content and methods to meet the specific needs and abilities of the students. These techniques included the following:

(a) students were divided into two groups: a more advanced group and a less advanced group;
(b) for the more advanced students, specialized tasks were prepared that extended beyond the standard curriculum requirements. These students could work on these tasks independently during the lecture while retaining the flexibility to follow the lecture content at their discretion;
(c) less advanced students were required to actively engage with the lecture material and participate in class activities;
(d students were allowed to self-select their group based on their self-assessment of their knowledge in the relevant subject matter;
(e) students were also permitted to switch groups as needed, depending on their level of knowledge in relation to specific topics.

This approach was designed to offer a customized learning experience that accounted for the varied levels of prior knowledge

within the student group. To ensure all students' comprehendsion of the material, a specific strategy was implemented for those with less advanced understanding. Students who felt uncertain about the topic were encouraged to work on problems at the blackboard, while those with partial understanding were tasked with solving the exercises independently in their notebooks. Over the years, this method has demonstrated its effectiveness, typically requiring only one lecture for students to adapt to the process. In subsequent lectures, students voluntarily approached the board, often competing to display their limited understanding, a behaviour indicative of a classroom environment that promotes inquiry and open discussion. Once a student successfully solved a problem at the board, the solution was compared to the work completed independently by other students to ensure consistency and accuracy.

For the more advanced group, modern pedagogical techniques and digital tools were used, such as software for simulating chemical molecules (e.g., 3D visualizations), audiovisual materials available online, educational games, and group-based problem-solving tasks. These methods not only facilitate a deeper understanding of the subject but also provide opportunities for student interaction, encouraging the exchange of knowledge and ideas. This collaborative process enhances communication skills and promotes the development of effective teamwork.

3.2. The absence of student motivation, coupled with the inability to contextualize the subject within its broader disciplinary framework and to relate it to other subjects in the core curriculum, presents a significant challenge.

A common issue in higher education is the low levels of student motivation and engagement. Many students adopt an instrumental approach to learning, focusing primarily on obtaining a diploma rather than on genuinely enhancing their knowledge and skills. This phenomenon is particularly evident among

students of environmental engineering in construction, the majority of whom view their future careers as primarily concerned with the design of sanitary systems. A relatively small proportion of students, typically around 10 %, express an interest in technological processes. Consequently, many students perceive the study of chemistry as an unnecessary burden, disconnected from the core focus of their academic program.

A key challenge, therefore, is to cultivate students' interest in the subject and to emphasize that an elementary understanding of chemical processes – and, at more advanced stages, technological processes – is essential to the broader field of environmental engineering. Additionally, an overly narrow specialization may lead to fragmented knowledge and a reduced ability to engage in holistic thinking, both of which are critical for success in the discipline.

Consequently, significant emphasis was placed on addressing this challenge within the instructional process. For each topic introduced, the relevance of the specific area of knowledge to future academic pursuits or professional practice was highlighted. By illustrating the connections between chemistry and other disciplines, such as biology, physics, and engineering, students were able to gain a better understanding of how their chemical knowledge could be applied to solving real-world problems.

Furthermore, students were actively encouraged to engage in information sharing and discussions whenever possible. For example, at the beginning of a lecture on pH, rather than offering a preliminary explanation of the concept or associated terms, students were asked where they encountered the term "pH" in their daily lives. It became apparent that while the students did not fully understand the scientific concept of pH, they frequently encountered it in various contexts, particularly in advertisements for hygiene products, food items, and pharmaceuticals. By highlighting that they already possessed a degree of familiarity with the topic, grounded in real-world applications, their interest in the subject was heightened. This strategy effectively

stimulated their engagement and maintained active participation throughout the lecture.

3.3. The lack of students' engagement during lectures

To encourage students to take a greater interest in the material presented during lectures, each session concluded with a brief summary of the content using an interactive quiz facilitated by applications such as Kahoot or Mentimeter. The top three students who scored the highest points in each quiz were tracked, and their cumulative scores were recorded at the end of the semester. Since students participated using anonymous nicknames, their individual scores remained unknown until the conclusion of the course, which provided additional motivation for competition while simultaneously encouraging permanent engagement with the lecture material. Ultimately, those students who accumulated the highest number of points received a higher grade for the course.

A valuable opportunity to bridge theoretical knowledge with practical applications, thereby enhancing student engagement, emerges in the discussions of environmental issues within the framework of chemistry instruction. For example, when teaching about different types of oxides, discussions were consistently invigorated by examining their role in the formation of smog, acid rain, and the greenhouse effect, as well as their broader implications for contemporary environmental challenges. This timely and relevant subject matter not only stimulated enthusiastic debates but also encouraged students to pursue further independent research on the topic.

3.4. The lack of critical thinking skills

Teaching of chemistry should prioritize the development of analytical skills and the cultivation of critical thinking abilities. The aforementioned integration of instructor-led debates and case analyses within the lecture structure strengthens students'

ability to critically assess data and make evidence-based decisions.

3.5. The lack of time to absorb and repeat the material at home

The traditional approach to studying, which often involved spending long hours in libraries searching for reference materials, has largely been replaced by the widespread availability of digital educational resources, such as e-books, e-learning platforms, video lectures, and simulations. Consequently, educators, including those in higher education, must put in additional effort to engage students, which presents a particular challenge in lecture-based teaching.

In the context of chemistry education, it is crucial that students systematically assimilate the material, as each successive topic builds upon the understanding of preceding concepts. This necessitates consistent reinforcement and consolidation of acquired knowledge on the part of the student. However, in the contemporary academic environment, students increasingly balance their studies with work or other extracurricular commitments. Many undertake part-time employment alongside their academic pursuits, and in recent years, some also begin working in roles related to their future profession. Therefore, it is imperative to ensure that students gain as much relevant knowledge and practical skills from their university experience as possible, preparing them for both their immediate academic challenges and their future careers.

The project was based on the assumption that students do not engage in reviewing material from previous classes at home, and consequently implemented the following strategies to facilitate the assimilation and consolidation of knowledge:

(a) at the beginning of each lecture, three minutes were dedicated to revisiting the material covered in the previous session, providing a brief summary, and emphasizing how the

previous topic is connected to the current lecture's content.

(b) at the conclusion of each lecture, as previously mentioned, the most relevant points were summarized through an interactive quiz. Importantly, after all students had answered the quiz questions, a discussion of the responses followed, starting with the incorrect answers, with clear explanations provided to highlight the nature of the errors.

(c) key content and self-practice exercises were made available on the e-learning platform, ensuring that students could access the teaching materials at their convenience, from any location and at any time.

4. Observations

The implementation of the described teaching strategies and methods resulted in a notable improvement in the quality of education, both qualitatively and quantitatively, compared to previous years. Namely, as far as the qualitative aspects are taken into consideration, a significantly greater number of students began actively participating in classes and demonstrated an increased interest in relating lecture topics to real-world events. Moreover, many students continued to engage with the material beyond the classroom, frequently sharing recent news articles, particularly on environmental issues, with the author even after the course had concluded. Additionally, a considerable number of students explicitly reported a marked improvement in their attitude towards the subject of chemistry.

From a quantitative perspective, in previous years, approximately 80 % of students enrolled in the Chemistry for Sanitary Engineering course took the first available exam, with an average of 20 % passing on their first attempt. Following the implementation of the new teaching methods, nearly 100 % of students now take the first exam, with approximately 40 % passing on their first attempt. This reflects an increase in the pass rate by over 20 %. According to the author, this indicates a significant shift in students' attitudes towards the subject, as they

demonstrate greater openness and interest in chemistry, which leads to a more confident approach to assessing their knowledge. A positive upward trend was also noted with regard to the grades received – compared to the situation before the experiment, the average exam grade (calculated for grades received during the 3 possible attempts) increased from 3.2 to 3.5. There was also a roughly 10 % improvement in the average exam grade.

5. Conclusions

Higher education is currently facing numerous challenges due to significant global transformations in the social, technological, economic, and political spheres. As follows, these challenges demand that institutions of higher education adapt quickly and effectively to ensure the continued relevance and quality of the instruction they offer. Specifically, these global shifts are reshaping the skills and competencies required for students to succeed in an increasingly complex and interconnected world. In response to these evolving demands, educators have sought innovations by developing and implementing modern pedagogical methods that can better equip students for both academic success and professional adaptability, which seems especially critical in fields like chemistry, where the rapid advancement of science and technology necessitates continual updates in teaching approaches.

In recent years, various modern pedagogical techniques have been introduced to enhance the teaching of chemistry at the university level, particularly within specialized courses such as *Chemistry for Sanitary Engineering* in the *Environmental Engineering in Civil Construction* program. Traditional lecture-based teaching methods, which primarily involve the passive transmission of theoretical knowledge, have proven insufficient in meeting the needs of today's students. Students increasingly expect a more engaging, interactive, and applied learning experience that not only conveys knowledge but also equips them with practical skills relevant to their future careers. In response to

these expectations, contemporary didactic approaches emphasize student-centred teaching, critical thinking, and the application of knowledge in real-life situations.

One of the primary objectives of implementing modern teaching strategies in chemistry education has been to improve teaching efficiency and, by extension, student learning outcomes. The move toward interactive and engaging methods has demonstrated considerable potential in fostering a deeper understanding of complex chemical concepts, which are often abstract and difficult for students to grasp through traditional lectures alone. By integrating practical activities such as laboratory simulations, real-world case studies, and problem-based learning, students are not only able to understand the theoretical underpinnings of chemistry but also see how these principles are applied in real-world engineering contexts.

For instance, in the context of teaching Chemistry for Sanitary Engineering, case studies related to environmental challenges such as water treatment, waste management, and pollution control provide students with a practical framework for understanding how chemical processes are integral to solving contemporary engineering problems. This applied approach not only increases the relevance of the subject matter to students but also enhances their motivation to engage with the content.

Moreover, the introduction of interactive technologies, such as e-learning platforms, 3D simulations, and virtual laboratories, has significantly transformed the learning environment. These tools allow students to visualize complex molecular structures and chemical reactions in a way that was previously impossible in a traditional classroom setting. For example, 3D simulations can help students explore the spatial orientation of molecules, enabling them to better understand stereochemistry and reaction mechanisms. Virtual laboratories also offer students the opportunity to perform experiments in a controlled, risk-free environment, where they can make mistakes and learn from them without the constraints of physical lab resources.

In addition to technological innovations, modern pedagogical methods in chemistry education place a strong emphasis on the

development of critical thinking skills. Unlike rote memorization, which was often emphasized in traditional chemistry instruction, critical thinking encourages students to analyse, evaluate, and synthesize information from multiple sources. This approach is particularly beneficial in fostering scientific inquiry, as students learn to question assumptions, formulate hypotheses, and draw evidence-based conclusions. Encouraging critical thinking prepares students not only for academic success but also for professional challenges, where problem-solving and adaptability are essential skills in a rapidly changing world.

The implementation of these contemporary teaching strategies has produced positive results in terms of both student engagement and satisfaction. In the specific context of the Chemistry for Sanitary Engineering course, student feedback has consistently indicated that the integration of real-world examples, interactive technologies, and problem-solving activities have enhanced the accessibility and making us of the material. Moreover, quantitative data has demonstrated improvements in exam performance, pass rates, and overall course satisfaction.

Nevertheless, the successful implementation of these teaching methods also presents certain challenges. One of the primary concerns is the need for ongoing evaluation and adaptation. While the initial results of these methods are promising, it is crucial to continuously monitor their effectiveness in response to changing educational conditions and student needs. For example, as new technologies emerge and societal demands evolve, educators must remain flexible and open to incorporating new tools and techniques into their teaching practice. Furthermore, there is a need for more research into the long-term impacts of these methods on student learning outcomes and professional development. While short-term improvements in engagement and satisfaction are encouraging, it is important to determine whether these methods ultimately lead to better career readiness and lifelong learning.

In conclusion, modern pedagogical methods in higher education are not only a response to the shifting demands of the educational landscape but also a critical tool for preparing future

graduates to thrive in an increasingly complex world. By integrating interactive technologies, real-world applications, and a focus on critical thinking, educators can provide a more effective and inspiring learning experience for students. However, the continued success of these methods depends on their ongoing evaluation and adaptation to ensure they meet the evolving needs of both students and the broader society. As higher education institutions continue to confront global challenges, the ability to innovate and adapt teaching practices will remain essential to fostering the next generation of skilled professionals and critical thinkers.

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