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Exploration of Blended Teaching Methods and Reform Measures in Analytical Chemistry

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Abstract: Analytical Chemistry is a course that closely links with students majoring in related fields and relates to daily life. Traditional teaching is no longer able to meet the needs of students. Therefore, to achieve the training objectives and to cultivate a scientific spirit, we propose turning to student-centered blended learning with mixed online and offline platforms. This form of teaching not only arouses student interest and encourages active learning but also meets various learning needs and fosters a careful scientific attitude, solving problems, and the ability to innovate. With the new model, students will change from passive receivers to active seekers and producers. They have active classroom discussions and academic debates while spending more and more time in independent study on the Internet with an ever-expanding knowledge base. They shifted their role from traditional teachers to guides and collaborators. They guide students to realize knowledge and encourage problem-solving and innovation. The model of this education does not only develop students but also infuses energy into the reform of education. Future attempts will highlight the elaboration of the improvements in this model to enhance the quality of teaching further and, with great significance, contribute to developing innovative talents.

1. Introduction

Analytical Chemistry, Organic, Physical, and Inorganic Chemistry all form the core quartet of chemical education. It is a foundational course compulsorily taught to majors in Chemistry, Chemical Engineering, Pharmacy, and Applied Chemistry, as well as those in the disciplines of Science, Engineering, Agriculture, Medicine, Environmental Science, and Biology. This is the reason behind the central role that Analytical Chemistry plays in any program of academia, bringing the necessity of updating teaching methodology from where independent learning, analytical and problem-solving skills can be imparted; teamwork, communication skills, and professional competency but with the infusion of patriotism, scientific mind, craftsmanship, labor ethics, and social responsibility. However, delivery is a problem because with only 32 classroom hours, teachers may often not handle the content extensively; too often, students have not been well engaged or learning differences addressed [1]. This has further hampered discussion, understanding of student learning dynamics, and overall student development. A rapid pace and uninspiring delivery on the part of the educator have also made it hard for active student participation in critical thinking and creative problem-solving. Besides, the high price of equipment for analytics and an extreme emphasis on theoretical knowledge transfer can make one miss the most profound understanding and the resulting practical skills. The latest achievements of information technologies offer weapons for educational reform in video micro-lessons, MOOCs, online classrooms, and teaching platforms, and virtual labs. All these new technologies support many online educational functions, such as resource management, monitoring attendance, assignments assessment, virtual experiments and testing, and teaching evaluation. It goes beyond traditional time and space boundaries to provide opportunities for continuous self-paced learning that can be adjusted and individualized according to the interests and needs of students. Therefore, online/ offline integration of the teaching mode of Analytical Chemistry could significantly enhance instructional quality and student outcomes. This paper discusses the potential of blended learning approaches in Analytical Chemistry and reform measures that could distill insights for practical guidelines relevant to the educator.

2. Teaching Status and Problems in Courses of Analytical Chemistry

The traditional teaching model of Analytical Chemistry has been a lecture for decades, where the teaching mainly followed textbooks, PowerPoint, and explanation on the blackboard with the wish that students consolidate their knowledge during exercise hours after class. To be consistent with fewer lecture hours, teachers should be given more detailed lectures but quickly, focusing on the principal theories without paying due attention to the peripheral topic, which results in a passive acquiring of knowledge with reduced overall efficiency. Analytical chemistry is one of the introductory courses of most STEM students. However, the rich content and many reaction equations, together with the complex mechanisms of such a course, make the usual single-mode offline classroom teaching not enough to cultivate the students' independent thinking and development of their cognitive ability. Online teaching based on modern information technology and internet platforms provides open learning resources and a virtual learning environment with flexible time and location, which helps in continuing learning and digests, strengthening basic knowledge. This model enables students to study autonomously due to the plentiful resources available, which range from every kind of content regarding Analytical Chemistry to that which can easily be shared, applied, and transformed. MOOCs also offer numerous high-quality courses in Analytical Chemistry, preparing and reviewing for university-level Analytical Chemistry classes as a highly important supplement. Fragmented online nature, however, can be a handicap for teaching complex subjects like Analytical Chemistry, for which students often lack the incentive to study complex topics in great depth, reduced cooperative and teamwork skills, concomitantly with an increase in self-directed learning. A hybrid "online-offline" teaching approach has been adopted increasingly [2]. Some examples are Tianjin University and East China University of Science and Technology, showing significant improvements in the engagement, analytical capabilities, and collaboration of students that are shown to outperform students in traditional classes. Other institutions, such as the Shanghai University of Applied Sciences and Northeast Agricultural University, have developed new models that interconnect micro-courses with the flipped classroom, hybrid class, online video lecture, and virtual laboratory methods and teacher guidance in an off-campus environment to complement teacher guidance. Such an approach uses the two formats' potentials in a way that augments improved learning results and encourages more integration into a complete educational experience. Therefore, it is essential to combine online and offline teaching methods to put into practice the quality of instruction in this relevant scientific discipline for the effective development of observation, analysis, and problem-solving skills in Analytical Chemistry.

3. Blended Teaching Model Analysis for Analytical Chemistry

3.1 Teaching Preparation

In the blended teaching model, the online and classroom teaching are integrated. The teachers teach students with instructions, and the students use online resources to study independently with engagement and interest. The first step is to collect the student's difficulties and their recommendations for the Analytical Chemistry Course through discussion and communication with previous groups. This information does provide an understanding of the problems, the effectiveness of each topic, and the likes of the teaching method. The teaching reform team looks into all this information—according to features, priority, and difficulty level of each chapter—and develops a good-blended teaching model. The objective is nurturing competent professionals capable of conducting participatory research. This teaching method is in sync with the contents of the course, and an understanding of what exactly is required by the students. An elaborate teaching plan and its operational strategy are founded on making collaborations between educational platforms and industrial partners stronger better to serve the experimental and creative potential of students. The mainstay of these efforts includes pre-class online questioning, in-class operational discussion, post-class training summary, autonomous virtual learning, cooperative practical exploration, precise explanations, and skillful operation of the experiment. The course content is constantly updated according to changes in the discipline, talent market demand, and teaching effect. The mainline courses, case studies, advanced topic lectures, and group discussions form the backbone of the new theoretical teaching framework. Mainline courses include such analytical methods as quantitative analysis, errors, and data handling in titrimetric methods, acid-base, complexometric, redox, and precipitation, gravimetric analysis, and spectrophotometry. All of them are introduced by an explanation of comprehensive analytical methods and principles of qualitative and quantitative research, separation, and enrichment of reaction products. Emphasis is placed on a problem-based and practical skills approach. Advanced topic lectures and discussions will extend curriculum focus to include leading theories and developments in the field, such as solution equilibrium theory, kinetics, precipitation and coprecipitation phenomena, indicator principles, titration curves and endpoint errors, and catalytic and induced reactions [3]. This ensures that students will understand current theories and developments in the field. Based on the "platform + resources + services" model, the Rain Classroom is a next-generation online teaching platform developed by Tsinghua University's Office of Online Education and XuetangX. The framework is usable with prior classroom hardware and can harmonize different teaching styles. Courseware, teaching assignments, videos, documents, etc., will all be provided with seamless storage and access, as they will be conveniently kept in the system. During the preparation phase, comprehensive video lectures are recorded by the teachers, and course materials-including lesson plans and question banks-are pre-published to enable students to preview the content that will be covered during the contact class. This is meant to build a very strong base of the course.

3.2 Implementation of Student-Centered Teaching

Present teacher-centered teaching doesn't fit the need to develop modern education. Blended learning is based on the philosophy of setting up a student-centered teaching class. The core idea of setting up a learning space lies in student-centered teaching in Analytical Chemistry. The capability of turning curriculum, content, teaching process, and evaluation system of student-centered teaching into high-quality talent cultivation is to target learning goals, knowledge structure, ability development, and competency standards. The teachers should respect such differences and encourage the students to think independently and speak out freely. This will maximize knowledge, skills, methods, and values integrated within the limited class time to realize the best educational outcomes. **1) Pre-class preparation:** teachers upload the course guide, lecture notes, exercise banks, and any link to high-quality online learning resources to the platform. The materials for challenging chapters, such as complexometric titration, redox titration, mass spectrometry, and NMR, are provided in PDF documents. It is required that students preview such material. The teacher supervises an online survey for class preparation and then adjusts the teaching plan, reminding those who have not done the task. **2) Combination of Classroom and Online:** The course combines classroom teaching with online self-study; usually, 2-4 discussion classes or special lectures are added every semester. Teachers reorganize class content and enrich it with cases, then deliver it in class through activities to enhance the problem-solving competence of students. Rain Classroom makes the seamless merge possible by pushing pre-class video, exercise, and audio content to students' mobile devices for their interaction and feedback in real time how all of that can be simply manipulated in such a way that a traditional classroom is transformed into a smart one: from group teaching to theme discussions and quiz contests, starting from attendance up to quizzes. **3) Flipped Classroom Discussing Sessions:** flipped classroom model in discussing sessions Students return to school for 6-Display secondary, literature review, group discussion and PPT presentation evaluation. These leverage special lectures on the developments and encourage students to question and practice their knowledge in the professional area. **4) Integration:** Teachers are not only giving the professional knowledge, but also integrating all elements in the curriculum system, so that the students can establish the correct outlook on the world, life, values and innovative spirits. The assignments may either be in the form of chapter tests or open-ended questions that are posted after the classes. Students accomplish this work on time, and teachers grade them timely feedback which they share to create understanding further on the same. **5) Taking the examples of Class Survey and Foreword Learning & Practice:** Discussion board allows classmates to explore class topics in depth and with proper extensions (like if one should evaluate the pros and cones of redox methods to determine berberine hydrochloride). The question and answer section would solve the students' questions and make them learn to think and solve the problems. With a blend of experimental design competitions and writing research reports it extends the creativity, teamwork and problem-solving abilities of the students. They are written in the style of core journal articles, but are limited in length and written in report format with abstract, introduction, methods and discussion sections. Students write to introduce their papers for formative evaluation, developing their literature review and summarizing skills. Involvement over the full cycle from experiment creation to video production nurtures a practical and creative competence.

3.3 Evaluation on a course

The traditional assessment on the experimental course is mainly based on the experiment report, it does not provide timely feedback, and the evaluation of the student is not comprehensive. The evaluation standards in the blended learning model set out learning styles, evaluation content - weightage, and submission schedules. The assessment has formative evaluations such as quizzes, thematic discussions, and summative evaluations such as final exams. Weight distribution is: Thematic discussions (Online+Classroom 10%), Quizzes (Online 20%), Practice (Classroom 20%) and Final assessment (Online+Classroom 50%) These results may be used for teachers' reflective teaching and student evaluation from professionalism and humanism in the contents and the methods of teaching to promote teaching reform in future. For instance, in the teaching of error analysis and data manipulation in Analytical Chemistry, teachers offer online resources and videos for self-study. Graded progress checks are assigned, group leaders are responsible for making sure everyone participates and discussion questions are posted in discussion or social media groups. The responses and scores build towards formative assessment and gives a holistic learning to the students. In offline learning, the attempt is to supplement the content that was presented online using PPTs and videos, highlighting the key points. Specified random questioning is also used by teachers to ensure attention and to prompt higher order thinking about error analysis and data handling. We evaluate student learning using a variety of assessment methods, both formative and summative. The multi-faceted method becomes more engaging and course-relevant. Feedback from teachers on student progress must be timely and objective to improve learning outcomes [4]. Towards the end of the course, teachers must summarize what they have achieved and reflect on anything they felt short or could have done better, with the aim of using this feedback and experience constructively to enhance teaching and help the students grow.

3.4 Reform Outcomes

Comparative analysis of students from the 2019, 2020, and 2021 cohorts reveals that the reformed teaching and assessment methods in "Analytical Chemistry" have significantly increased student engagement and improved learning outcomes. Tracking data indicates that students from the second class of Chemical Engineering and Pharmacy, who first experienced the reformed curriculum, participated in and won the most competitions compared to their peers. These students also demonstrated stronger independent experimental and innovative abilities, actively seeking literature and proposing student innovation and entrepreneurship projects [5]. They independently designed and executed experimental plans for these projects and faculty research initiatives. These successes not only validate the effectiveness of the teaching reforms but also provide valuable insights for future improvements. Moving forward, we will further deepen these reforms, continually optimizing teaching methods and assessment to better meet student needs and cultivate talented individuals with strong innovation and practical skills. We will also continue to support student development by providing more opportunities and platforms for them to enhance their abilities and qualities through practical experiences.

4. Challenges of Blended Teaching in Analytical Chemistry

4.1 Insufficient Teacher Proficiency in "Human-Machine Co-Teaching"

Blended teaching in Analytical Chemistry requires the integration of digital, networked, and intelligent platforms and tools such as the internet and artificial intelligence. This demand extends beyond technical use to the pedagogical wisdom needed to facilitate deep learning through technology. Teachers often lack proficiency in these technologies due to inexperience with new, intelligent, and personalized teaching platforms and software. Addressing this gap requires continuous learning and exploration. Teachers must engage in relevant training and workshops, sharing experiences and insights with colleagues to improve their technical skills and teaching abilities. This ongoing development is essential for adapting to the evolving educational landscape and providing high-quality, efficient teaching. Educational institutions must support teachers by offering necessary technological resources and creating a conducive teaching environment. Comprehensive training and guidance should be provided to help teachers effectively utilize new technologies and enhance their teaching effectiveness. Additionally, teachers should focus on developing students' autonomous learning abilities and innovative thinking by encouraging the use of various technological tools and resources to explore knowledge actively. By working together, teachers, schools, and educational institutions can maximize the benefits of blended teaching, fostering innovative and practical talents and advancing the education sector.

4.2 Varied Student Engagement in "Human-Machine Assisted Learning"

In technology-supported teaching, the role of technology extends beyond aiding teachers to include "human-machine assisted learning" for students. This helps ensure full classroom participation and allows teachers to monitor student progress and address issues promptly. While smart devices and digital learning tools generally enhance student engagement, individual experiences and participation levels can vary due to inconsistent access to technology, hindering deep learning and affecting outcomes. Teachers need to demonstrate patience and provide additional time to help students familiarize themselves with online learning processes. Under teacher guidance, students should progressively apply new knowledge and skills to solve real problems. Online learning demands high self-discipline, and remote supervision can be challenging. Teachers can collaborate with class monitors to oversee student progress and prompt timely feedback for any issues. Effectively integrating online and offline teaching content and methods to achieve optimal learning outcomes requires careful consideration. Teachers should design activities that help students gradually incorporate new knowledge into their existing understanding. This process enhances the connection between old and new knowledge, facilitating assimilation. Consolidation emphasizes reflection and reinforcement. Teachers should provide opportunities for discussion, peer collaboration, and peer review, guiding students to summarize and reflect on their learning while creating new practice opportunities to reinforce the new knowledge framework. By engaging with thoughtfully designed content and completing related tasks, students activate existing knowledge and skills in preparation for learning new concepts.

4.3 Providing Professional Development Support for Teachers in "Human-Machine Co-Teaching"

To enhance understanding and skills in "human-machine co-teaching," it is essential to offer teachers professional development support through training, courses, and practical opportunities. Teachers prefer practical, context-specific training that integrates technology with teaching, such as hands-on workshops that emphasize participation and real-world application. Training should focus on real teaching challenges, guiding teachers to become proficient in using technology creatively and collaboratively to solve problems, thus improving their technical practice. In-service training can effectively address the question of "how to teach" in a blended learning environment. In the blended teaching model, offline learning should be the primary method, supplemented by online resources. Teachers should emphasize the integration of comprehensive knowledge and connections between key points during offline classes, enhancing students' understanding and application. This approach allows students to refine, practice, and develop autonomous learning skills simultaneously. As societal changes and evolving information influence students' attitudes and interests, continuously updating learning resources and aligning them with student preferences is crucial for maintaining high learning efficiency. By keeping resources current and engaging, teachers can better meet students' needs and enhance overall educational outcomes.

5. Conclusion

The blended teaching model for Analytical Chemistry, combining online and offline methods, presents a promising educational approach. Despite the challenges, such as the time students need to learn platform skills and potential disparities in equipment access, and the continuous monitoring and support required from teachers, this model offers significant advantages over traditional methods. Students engage in pre-class autonomous learning, receive personalized guidance during class, and consolidate and expand their knowledge through post-class activities. This approach maximizes student engagement, respects individual differences, and facilitates student-centered, differentiated instruction. It helps cultivate a rigorous scientific attitude, meticulous scientific practices, and enhances students' creative problem-solving abilities. However, the implementation of this model also presents challenges that require ongoing exploration and innovation by educators. By improving teaching platforms, enhancing teacher-student interactions, optimizing teaching content and methods, and establishing robust evaluation and feedback mechanisms, we can advance the development of blended teaching in Analytical Chemistry. These efforts will contribute to the cultivation of more skilled and innovative chemistry professionals.

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