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# Revisiting Basic Chemistry Curriculum to Foster Adaptive Learning in Higher Education

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**Abstract**

The transformation of higher education in Indonesia presents challenges and opportunities for universities to develop adaptive learning ecosystems. This study aims to analyze the Semester Learning Plans (RPS) of Basic Chemistry courses to evaluate their alignment with digital-era learning needs. Using a qualitative approach, the research involves document analysis of 19 RPS, focusing on learning methods and the integration of digital technology. Data were validated through questionnaires distributed to lecturers in charge of these courses. Results reveal that active learning methods, such as Problem-Based Learning (PBL) and Project-Based Learning (PjBL), dominate, yet the integration of innovative technologies like virtual laboratories and software-based simulations remains limited. The study highlights the importance of adaptive learning strategies, digital literacy, and culturally responsive teaching to support global demands. New findings emphasize the need for systematic lecturer training and institutional support to enhance technological adoption in teaching. This research contributes to the development of more effective and inclusive learning environments, benefitting both science education and society.

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## INTRODUCTION

The transformation of higher Education in Indonesia presents challenges and great opportunities for universities to prepare competitive graduates for the global era. Changes triggered by the development of digital technology and the dynamics of global needs require universities to meet curriculum standards and proactively adapt to these changes. As an educational institution, universities have a strategic responsibility to create a learning environment that supports the development of graduates with flexible, innovative, and responsive abilities to global challenges and complex social changes (Sa'adah, 2020).

Although curriculum changes are an important step in adapting Education to the needs of society and technology, the more fundamental challenge lies in creating an adaptive and sustainable learning ecosystem. This environment allows students to continue learning and developing critical, collaborative, and creative thinking skills that are essential in facing the uncertainty of the world of work (Darmalaksana, 2020; Marwati et al., 2021). Previous studies have highlighted the importance of integrating adaptive learning models to address these challenges. For instance, Darmalaksana (2020) and Marwati et al. (2021) discuss the necessity of fostering critical and collaborative skills, yet their research does not explore how Semester Learning Plans (RPS) can systematically integrate these principles. Similarly, studies by Istanti, (2019) and Wati (2023) have emphasized the role of digital tools such as online platforms and AI-based simulations in enhancing learning outcomes. However, these studies lack an analysis of how these technologies are incorporated into specific curriculum documents like RPS, leaving a gap that this research aims to address. The development of digital technology also provides a new dimension for learning. Online platforms, virtual laboratories, technology-based simulations, and artificial intelligence (AI)-based tools can enrich the student learning experience (Istanti, 2019; Wati, 2023). Integrating this technology is a learning tool and a medium that can simulate various real-world scenarios relevant to students' disciplines (Indrawan, 2023). Digital literacy and technology skills are becoming increasingly crucial for graduates in this era (Rahman, 2020).

Furthermore, this technology-based learning approach supports a student-centered learning paradigm (student-centered learning) (Second, 2023). By utilizing methods such as project-based learning, problem-based, and inquiry-based, Students can take an active role as learning agents (Apsari et al., 2019; Cahyani, 2021; Lesnowati & Hafifi, 2021; Mite et al., 2021). This approach allows them to learn through independent exploration, collaboration, and hands-on experience, strengthening analytical and adaptive abilities (Pokhrel & Chhetri, 2021; & Kim, 2014). However, the existing body of research often overlooks the structural and practical integration of these approaches within RPS. This study contributes to filling this gap by examining how RPS in Basic Chemistry courses align with adaptive and digital-era learning needs.

To ensure the effectiveness of this approach, universities must conduct periodic evaluations of learning strategies, including strategic documents such as the RPS. This evaluation ensures the relevance of learning materials to the world of work and supports the achievement of relevant competencies in the future. By creating an adaptive and innovative learning environment, universities can play a key role in producing graduates ready to face the challenges of the times (Cavanagh et al., 2020). This approach emphasizes that curriculum change is not an obstacle but an opportunity to create a more relevant and sustainable learning ecosystem (Magaña, 2023). Ultimately, universities that successfully integrate flexibility and technology in learning will be able to create a generation of lifelong learners who are competent and responsive to change (Mirata et al., 2020; Pattipawaej et al., 2023). Therefore, further studies are needed to explore the role of study programs in creating an adaptive and technology-based learning environment through basic chemistry courses. By examining strategies that can increase the flexibility and relevance of learning to the dynamics of the world of work, this research is expected to provide strategic insights for developing learning strategies in the digital era.

## METHODS

This study uses a qualitative approach with document analysis of 19 Semester Learning Plans (RPS) for the Basic Chemistry course (Creswell, 2015). The analysis is focused on the main elements of the RPS, such as learning methods and the level of technology integration in learning strategies. The study was conducted to determine the suitability of the learning strategies designed in the RPS with the principles of adaptive learning and needs in the digital era. The research was conducted systematically through the following steps:

1. Selection of Documents:
   a. A total of 19 RPS documents from various universities were collected.
   b. The documents were chosen based on their relevance to the Basic Chemistry course and their alignment with adaptive learning principles.
2. Content Analysis:
   a. Each RPS was reviewed to identify key components such as learning methods and the integration of digital technology.
   b. Specific elements analyzed included: Descriptions of learning strategies (e.g., project-based learning, problem-based learning, and group discussions); Use of technology-based tools such as online platforms and simulations.
3. Validation through Lecturer Feedback:
   a. A follow-up questionnaire was designed to gain insights from lecturers responsible for the Basic Chemistry course.
   b. The questionnaire, distributed via Google Forms, included open-ended questions to: Understand the rationale for selecting specific learning methods; Identify challenges in implementing technology-based strategies; Assess the perceived relevance of RPS to adaptive learning needs.
4. Data Interpretation:
   a. Data from document analysis and lecturer feedback were synthesized and interpreted descriptively.
   b. Patterns of alignment and gaps between RPS content and adaptive learning principles were identified.
5. Strategic Recommendations: Based on the analysis, strategic recommendations were developed to improve the RPS for better alignment with the demands of the digital era.

### Research Workflow

To clarify the research process, the following diagram illustrates the steps involved in this study:

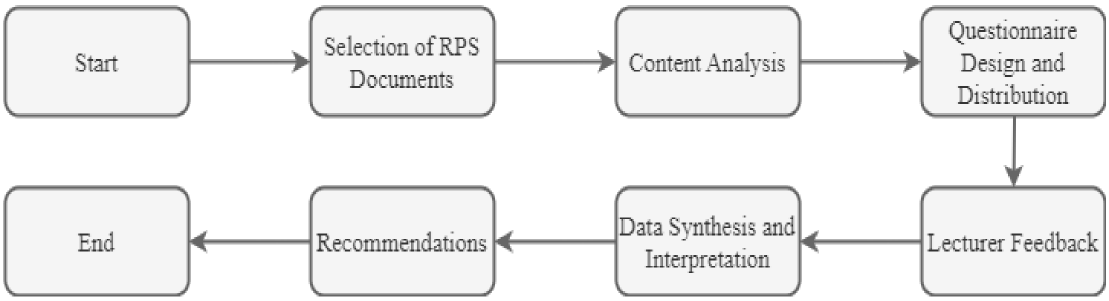


**Figure 1.** Research Workflow

Description of Workflow

1. Start: Defined the research objectives and identified the scope of the study.
2. Selection of RPS Documents: Gathered and reviewed 19 RPS documents from various universities.
3. Content Analysis: Identified and categorized learning methods and technology integration using a predefined framework.
4. Questionnaire Design and Distribution: Developed a Google Form to gather lecturer insights.
5. Lecturer Feedback: Analyzed lecturer responses to validate and enrich findings.
6. Data Synthesis and Interpretation: Integrated all findings to identify patterns and develop recommendations.

7. End: Finalized strategic insights for adaptive learning in Basic Chemistry courses.

This structured approach ensures that the methodology aligns with the research objectives and provides actionable insights for improving learning strategies in higher education.

## RESULTS AND DISCUSSION

### Characteristics of Adaptive Learning Environment

The analysis of the documents on 19 Basic Chemistry RPS shows that some active learning methods, such as Problem-Based Learning (PBL), Case-Based Learning, and Project-Based Learning (PjBL), have been a top choice in many study programs. This method provides students with relevant, real-world, problem-based learning experiences, which help students develop critical thinking, collaboration, and problem-solving skills (Pradanti & Muqtada, 2023; Usmeldi & Amini, 2022). These methods align closely with the demands of 21st-century education, which emphasizes not only subject knowledge but also transferable skills crucial for interdisciplinary problem-solving. The integration of PBL and CBL in particular allows students to actively engage with real-world scenarios, preparing them to address practical challenges in their future careers (Almulla, 2020; Kusumawati et al., 2019; Rendón-Castrillón et al., 2023). This finding underscores the importance of designing curricula that bridge theoretical concepts and real-life applications, ensuring that students gain both knowledge and practical competence. This method reflects the study program's awareness of the needs of the digital era, where students are required to be actively involved in learning (Alenezi, 2023; Reyes et al., 2022).

However, there needs to be more adoption of certain learning methods. Self-directed learning and culturally responsive teaching still need to be applied. However, this method is important for forming independent learners sensitive to diverse cultural contexts. The lack of emphasis on these methods highlights a critical gap in fostering student autonomy and cultural adaptability, both of which are essential for navigating the increasingly globalized workforce. Self-directed learning empowers students to take ownership of their educational journey, cultivating skills in time management, goal-setting, and lifelong learning (Schaller et al., 2023; Wang et al., 2024). On the other hand, culturally responsive teaching provides a framework for inclusivity, ensuring that diverse student backgrounds are respected and integrated into the learning process. Neglecting these methods not only limits the holistic development of students but also risks marginalizing learners from varied cultural contexts, thereby reducing the overall effectiveness of educational outcomes. This lack of adoption can hinder the development of students' skills to learn independently and work in a multicultural environment (Bashir et al., 2021). In addition, conventional learning methods such as the Lecturing Method are still a mainstay in several study programs, especially for materials that require theoretical mastery. Although relevant for basic delivery, the high reliance on lectures has the potential to limit student involvement in more interactive and in-depth learning (Kurniawan et al., 2020).

The distribution of learning methods in the study program also shows the need to add or vary learning strategies. Methods such as Discovery Learning and Inquiry-Based Learning, which can help students explore material in depth, still need to be improved. This indicates an opportunity to expand the application of learning methods that support deep learning and exploration-based. Expanding these strategies is crucial for developing a deeper understanding of complex concepts, particularly in subjects like chemistry that often require hands-on experimentation and critical analysis. Discovery Learning encourages students to uncover new knowledge independently, fostering curiosity and innovation, while Inquiry-Based Learning promotes systematic exploration and evidence-based reasoning. By incorporating these methods more extensively, educators can create a dynamic and stimulating learning environment that not only builds academic proficiency but also nurtures critical thinking and problem-solving abilities essential for scientific advancement. Based on the analysis of 19 RPS, various learning methods have been adopted in universities, as visualized in Figure 1 below.

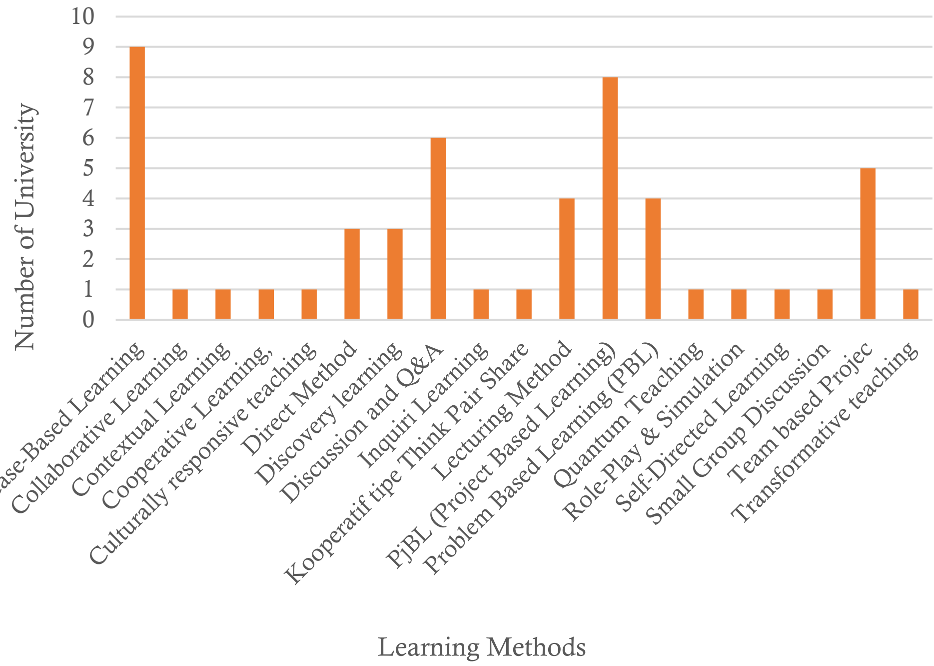


**Figure 2.** Distribution of Learning Methods in the Chemistry Education Study Program

Activity-based learning methods, such as PBL, CBL, and PjBL, are the most dominant methods, each used by 7 to 9 study programs. These methods are relevant to adaptive learning principles because they involve students directly in real problem-solving and applied projects. The frequent use of these methods reflects a growing recognition of their effectiveness in bridging theoretical and practical knowledge. However, the uneven adoption of other complementary strategies such as Inquiry-Based Learning suggests a missed opportunity to fully diversify pedagogical approaches. By emphasizing a broader mix of active learning techniques, universities can cater to varying student needs and learning styles, ensuring a more inclusive and impactful educational experience. Figure 1 shows the distribution of the adoption of learning methods in the study program. The Case-Based Learning method (9 study programs) and Problem-Based Learning (7 study programs) are the most frequently used, followed by the Inquiry Learning and Discovery Learning methods. This method develops students' critical thinking, analytical, and collaborative skills. Meanwhile, context-based and independent methods, such as Self-Directed Learning, Culturally Responsive Teaching, and Contextual Learning, still need to be applied, with each only being applied in 1-2 study programs.

In addition, small group discussions are used in some study programs, but they are more complementary than the main approach. Meanwhile, the more conventional lecturing method is still used in several study programs for materials that require in-depth theoretical explanations. Although the lecture method effectively delivers basic concepts, a higher reliance on this method can reduce student involvement in more active and in-depth learning. This reliance highlights the tension between traditional and modern pedagogical approaches in chemistry education. While lectures remain indispensable for explaining foundational theories and concepts, their overuse may disengage students and hinder opportunities for collaborative and experiential learning (Saad et al., 2024). To strike a balance, educators should consider integrating interactive tools and active participation exercises, such as peer teaching and flipped classrooms, into traditional lecture formats (Bae et al., 2021). Such integration can revitalize the learning experience and ensure that theoretical knowledge is effectively translated into practical competence. Adopting this learning method reflects the study program's efforts to integrate adaptive learning principles (Cavanagh et al., 2020).

**Challenges and Implementation**

One of the main challenges identified is the need for more technology integration in learning. Only some study programs effectively use technology, such as animation videos or digital learning platforms. This technology can enrich students' learning experience, especially in Basic Chemistry courses that often require visualization of abstract concepts. For example, the use of virtual laboratory simulations can replace the limitations of physical practicum and provide students with interactive experimental experiences. However, the lack of access to advanced technological tools, coupled with insufficient technical training for educators, creates a gap in maximizing the potential of these resources. Virtual laboratories, for instance, can significantly enhance conceptual understanding by simulating intricate chemical processes in an engaging and interactive manner. To address this, universities must not only invest in procuring these tools but also ensure continuous technical support and training for educators, enabling effective integration into the curriculum.

Another challenge is the competence of lecturers in designing and implementing technology-based learning methods. Some lecturers may be familiar with traditional lecture methods and need adequate training to use technology-based methods. In addition, the limited time required to implement activity-based learning methods such as PjBL or PBL is also a challenge. This method takes longer to plan and implement than conventional lecture methods. In an academic environment with a tight schedule, lecturers may need help applying this method optimally. The following is presented in Figure 3 regarding the use of media in basic chemistry training.

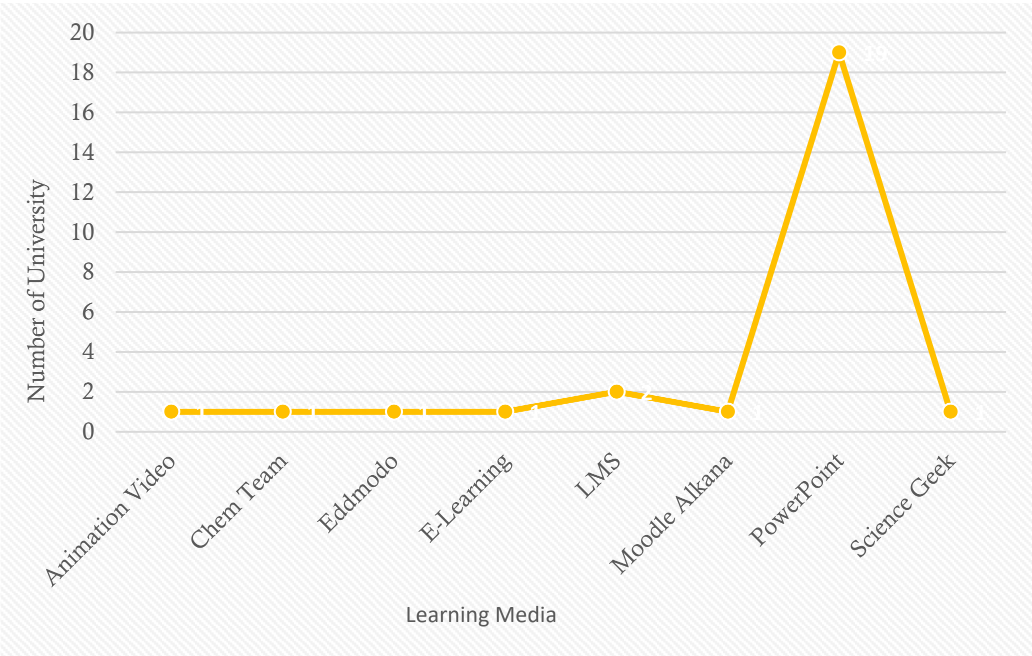


**Figure 3.** Learning Media

Based on the data analysis on graphs that illustrate the total use of various learning platforms in several universities, there is a significant gap in adopting digital technology to support learning. This graph shows that PowerPoint is the most dominant learning medium used by 19 chemistry education study programs. This dominance indicates that most university lecturers use presentation-based media to deliver material. Although PowerPoint provides flexibility in the delivery of information, the reliance on this medium reflects the limitations of integrating more interactive and adaptive learning technologies, which can provide students with a more dynamic and immersive learning experience. The reliance on PowerPoint suggests a preference for convenience over innovation, which limits opportunities for engaging students in active learning. Interactive tools like simulations or virtual labs can make abstract concepts more tangible, encouraging deeper exploration and understanding. To bridge this gap, institutions should provide access to advanced platforms and training on their effective use, promoting a shift from passive information delivery to active learning experiences.

Meanwhile, other digital learning platforms, such as the Learning Management System (LMS), are only used by two universities, showing that the utilization of this system still needs to be improved. Platforms like LMS have great potential to support collaborative learning, manage assessments, and provide broader access to structured learning materials (Dikananda et al., 2019; A. A. Rahman et al., 2020). However, this data shows that this potential has yet to be fully utilized. The limited adoption of LMS reflects missed opportunities to enhance the structure and accessibility of learning resources. LMS platforms can serve as a centralized hub for collaboration, feedback, and resource sharing, fostering a cohesive learning environment. Expanding their use requires institutional commitment to training educators and integrating these systems into regular teaching practices (Meyer et al., 2024). Moreover, tailoring LMS functionalities to specific course needs can further amplify their impact, creating a more personalized and effective educational experience. In addition, one university has only adopted other platforms such as Edmodo, Moodle Alkana, and E-Learning-based applications, confirming the need for more diversification in the use of learning technology in universities.

In addition, using more innovative technologies such as animated videos and field-specific applications such as Science Geek is even less visible, each used by only one university. This situation emphasizes the gap in adopting technology to provide a richer and more contextual learning experience, especially in courses such as Basic Chemistry. For example, animated videos can help students understand abstract concepts such as molecular structure, chemical reaction dynamics, or reaction mechanisms, which are difficult to explain only through static media such as PowerPoint. The lack of adoption of these tools suggests a need for targeted efforts to integrate modern technologies into teaching practices. Animations and field-specific applications not only enhance comprehension but also sustain student interest by making learning more engaging and relatable. To overcome this gap, universities should prioritize the inclusion of these tools in their curricula, complemented by workshops and training for educators. Partnerships with technology providers could also facilitate access to these resources, making their implementation more feasible and widespread.

The reality that PowerPoint is the main choice indicates challenges in implementing technology-based learning in universities. One of these challenges is the need for more utilization of more advanced learning technologies, such as the use of virtual laboratories or software-based simulations. This technology is very relevant for learning in Basic Chemistry courses requiring complex concept visualization. The low adoption rate of this technology shows the need for strategic steps to introduce and train lecturers in utilizing available technology. Other challenges may be due to infrastructure barriers, such as limited stable internet access or adequate hardware, which also hinder the application of more innovative learning technologies. Another obstacle is the limited time of lecturers in designing technology-based learning, especially methods that require more complex preparation and implementation. Addressing these challenges demands a multi-faceted approach, combining infrastructure investments with professional development initiatives. Stable internet access and modern hardware are prerequisites for leveraging advanced technologies, while workshops and peer mentoring programs can help educators adapt to these tools. Moreover, revising academic schedules to allocate time for the planning and implementation of innovative teaching methods can ease the burden on lecturers, making these approaches more practical and sustainable (Dolci et al., 2024).

In the context of Chemistry Education, courses such as Basic Chemistry, which require understanding abstract concepts, can utilize effective media such as animated videos, interactive simulations, or science-based digital applications. However, this data shows that the technology still needs to be fully implemented. This can also hinder universities' efforts to create learning relevant to the needs of students in the digital era and the challenges of Industry 4.0. Universities need to invest in technology infrastructure and provide intensive training to lecturers to improve digital literacy (Svensson et al., 2022). In addition, encouragement is needed from institutions to promote innovation in learning design so that existing technology can be integrated with methods that suit the learning needs of students. The integration of such technologies not only aligns education with the demands of Industry 4.0 but also equips students with digital competencies crucial for future employment. Institutional policies must prioritize technological adoption by allocating resources for infrastructure upgrades and creating incentives for educators to innovate their teaching practices. Additionally, fostering collaborations between academia and industry can provide insights into emerging technological trends, ensuring that educational content remains relevant and forward-looking (Oktariani et al., 2020).

Figure 3 above provides a clear picture of the need for transformation in the learning approach in the study program, especially in chemistry education. Universities need to be more proactive in supporting the adoption of innovative learning technologies to create a more relevant learning experience that engages student needs. This transformation requires the development of lecturer skills and adequate infrastructure support to ensure the successful implementation of technology in learning. Thus, wider technology integration will answer educational challenges in the digital era and support the development of student competencies that are ready to face future challenges. This transformation is not just a technological shift but a cultural change in educational practices, emphasizing collaboration, innovation, and adaptability. By championing these values, universities can position themselves as leaders in producing graduates who are well-equipped to thrive in an ever-evolving global landscape.

**Strategies for Overcoming Obstacles**

To overcome these challenges, an integrated strategy is needed in terms of institutional policies and lecturer competency development. First, the study program can encourage the adoption of the Self-Directed Learning method by training lecturers to design learning strategies that support student independence. Supporting platforms such as the Learning Management System (LMS) can also be leveraged to allow students to access learning resources independently. LMS platforms, as highlighted by Cavanagh et al., (2020), can provide structured and flexible access to materials, promoting a student-centered approach and fostering independent learning habits (Rahman et al., 2020).

Second, the combination of lecture and active learning methods must be applied more widely. Lectures can be used as an introduction to provide basic knowledge, while methods such as PBL and group discussions deepen students' understanding of the material. This combination not only enhances interaction in the classroom but also ensures conceptual and applicative mastery of the material. Research by Pokhrel & Chhetri (2021) indicates that a balance between traditional and active learning fosters critical thinking while maintaining clarity in theoretical foundations (Magaña, 2023).

Third, lecturer training in learning technology is a priority. Universities can hold regular training sessions to introduce lecturers to technology such as digital simulations, virtual laboratories, and data analysis software. This training equips lecturers with the necessary skills to design interactive learning experiences that align with student needs and industry demands. Magaña (2023) emphasizes that such training programs should be iterative and adaptive, allowing lecturers to gradually integrate innovative tools into their teaching practices(Tang, 2023).

Fourth, contextual methods such as culturally responsive teaching can be strengthened by encouraging lecturers to integrate local and cultural examples into learning. Specialized training on teaching responsive to cultural diversity can guide lecturers in embedding cultural contexts into student assignments or projects. Tang (2023) underscores the importance of culturally contextual learning in fostering inclusivity and engagement, especially in diverse educational settings. Additionally, promoting these methods helps prepare students for multicultural work environments, enhancing their adaptability and collaborative skills Pattipawaej et al (2023)

By implementing these strategies, universities can address current challenges in integrating adaptive learning methods and ensure that their graduates are better equipped for future demands (Cavanagh et al., 2020; Pattipawaej et al., 2023)

**Application in the Context of Higher Education**

In the context of the study program, the application of methods such as PBL, PjBL, and Case-Based Learning can be systematically integrated into the RPS. Study programs can develop policies to encourage using this method in every course, especially basic courses such as Basic Chemistry. This integration ensures that students are actively engaged in problem-solving and critical thinking processes, which are essential for real-world applications (Arianto & Fauziyah, 2020; Kong et al., 2024; Mite et al., 2021).

In addition, study programs can utilize digital technology to support this learning method. For example, PBL can be strengthened with an online collaboration platform that allows students to work in groups virtually (Consoli et al., 2023). Platforms such as LMS and specialized tools like Google Workspace or Microsoft Teams enable seamless virtual collaboration, fostering teamwork and communication skills (Kousloglou et al., 2023; Li et al., 2022; Saad et al., 2024) .

Virtual laboratories in Basic Chemistry courses can also be increased to complement physical practicums that may be limited due to time constraints or facilities. Students can conduct experimental simulations using virtual labs to develop analytical and problem-solving skills. Studies by Sanzana et al., (2024) highlight that virtual laboratories provide an effective way to visualize complex concepts and practice experimental methods without the constraints of physical setups. Furthermore, Magaña, (2023) underscores the role of adaptive virtual simulations in personalizing student learning experiences and increasing engagement.

Implementing adaptive learning strategies that utilize technology, support independent learning, and are relevant to the cultural context will ensure that universities can produce graduates ready to face global demands. Adaptive learning models, as emphasized by Cavanagh et al., (2020), not only prepare students for diverse professional environments but also enhance their capacity for lifelong learning by tailoring educational content to individual needs (Tuncel & Bahtiyar, 2015)

## CONCLUSION

This study emphasizes the importance of transforming the learning environment in higher Education to create competent, innovative graduates responsive to the challenges of the digital era. The findings show that active learning methods such as Problem-Based Learning (PBL) and Project-Based Learning (PjBL) have been widely adopted. However, there still needs to be more integration of advanced learning technologies such as virtual laboratories and software-based simulations. Limitations in the use of technology due to infrastructure limitations are one of the obstacles to integration with learning. Strategies for integrating technology-based learning methods, lecturer training, and strengthening cultural contexts can support adaptive learning that is relevant to global needs. Universities need to invest in technology infrastructure and strengthen technology-based learning policies. With this strategic step, universities can play a key role in producing a generation of lifelong learners ready to face the dynamics of the world of work.

## REFERENCES

Alenezi, M. (2023). Digital Learning and Digital Institution in Higher Education. *Education Sciences*, *13*(1). https://doi.org/10.3390/educsci13010088

Almulla, M. A. (2020). The Effectiveness of the Project-Based Learning (PBL) Approach as a Way to Engage Students in Learning. *SAGE Open*, *10*(3). https://doi.org/10.1177/2158244020938702

Apsari, Y., Mulyani, E. R., & Lisdawati, I. (2019). Students' Attitudes Toward Implementation of Project Based Learning. *Journal of Educational Experts (Jee)*, *2*(2), 123. https://doi.org/10.30740/jee.v2i2p123-128

Arianto, H., & Fauziyah, H. N. (2020). Students' Response To the Implementation of Case Based Learning (Cbl) Based Hots in Junior High School. *INSECTA: Integrative Science Education and Teaching Activity Journal*, *1*(1), 45–49. https://doi.org/10.21154/insecta.v1i1.2058

Bae, S. W., Lee, J. H., & Park, J. (2021). Development of a Field-Based Chemistry Experiment Teaching Model to Strengthen Pre-Service Teachers' Competence for Teaching Chemistry Experiments. *Asia-Pacific Science Education*, *7*(2), 522–548. https://doi.org/10.1163/23641177-bja10037

Bashir, A., Bashir, S., Rana, K., Lambert, P. A., & Vernallis, A. B. (2021). Post-Covid-19 Adaptations; The Shifts Towards Online Learning, Hybrid Course Delivery and the Implications for Biosciences Courses in the Higher Education Setting. *Frontiers in Education*, *6*. https://doi.org/10.3389/feduc.2021.711619

Cahyani, N. K. C. (2021). Effectiveness of Project-Based Learning Models in Improving Students' Creativity (A Literature Review). *The Art of Teaching English as a Foreign Language*, *2*(1), 73–77. https://doi.org/10.36663/tatefl.v2i1.107

Cavanagh, T. B., Chen, B., Lahcen, R. A. M., & Paradiso, J. (2020). Constructing a Design Framework and Pedagogical Approach for Adaptive Learning in Higher Education: A Practitioner's Perspective. *The International Review of Research in Open and Distributed Learning*, *21*(1), 172–196. https://doi.org/10.19173/irrodl.v21i1.4557

Consoli, T., Désiron, J., & Cattaneo, A. (2023). What is "technology integration" and how is it measured in K-12 education? A systematic review of survey instruments from 2010 to 2021. *Computers & Education*, *197*, 104742–104742. https://doi.org/10.1016/j.compedu.2023.104742

Creswell, J. W. (2015). *Educational research: Planning, conducting, and evaluating quantitative and qualitative research* (Fifth edition). Pearson.

Darmalaksana, W. (2020). Ekspektasi Pembelajaran Berbasis Kurikulum: Studi Kasus Pengajaran Mata Kuliah Metode Penelitian Pada Program Studi Ilmu Hadis. *Khazanah Pendidikan Islam*, *2*(3), 114–125. https://doi.org/10.15575/kp.v2i3.9530

Dikananda, A. R., Santoso, H. B., Dana, R. D., & Sudrajat, D. (2019). E-Learning Usability Evaluation Menggunakan Fuzzy Logic Dan Usulan Alternatif Desain Interaktif Learning Management System (LMS) Chamilo. *Jurnal Ict Information Communication & Technology*, *18*(1), 65–70. https://doi.org/10.36054/jict-ikmi.v18i1.56

Dolci, V., Bigliardi, B., Petroni, A., Pini, B., Filippelli, S., & Tagliente, L. (2024). Integrating Industry 4.0 and Circular Economy: A Conceptual Framework for Sustainable Manufacturing. *Procedia Computer Science*, *232*, 1711–1720. https://doi.org/10.1016/j.procs.2024.01.169

Ha, I.-K., & Kim, C. (2014). The Research Trends and the Effectiveness of Smart Learning. *International Journal of Distributed Sensor Networks*, *10*(5), 537346. https://doi.org/10.1155/2014/537346

Indrawan, M. A. (2023). Pengembangan Sistem Manajemen Dokumen PKM Universitas Islam Indonesia. *Syntax Literate Jurnal Ilmiah Indonesia*, *8*(6), 4276–4287. https://doi.org/10.36418/syntax-literate.v8i6.12596

Istanti, D. J. (2019). Dinamika Kebijakan Kurikulum Pendidikan Di Indonesia Pasca Reformasi. *Jurnal Ilmu Politik Dan Pemerintahan*, *5*(2), 140–156. https://doi.org/10.37058/jipp.v5i2.1537

Kong, S.-C., Cheung, M.-Y. W., & Tsang, O. (2024). Developing an artificial intelligence literacy framework: Evaluation of a literacy course for senior secondary students using a project-based learning approach. *Computers and Education: Artificial Intelligence*, *6*, 100214–100214. https://doi.org/10.1016/j.caeai.2024.100214

Kousloglou, M., Petridou, E., Molohidis, A., & Hatzikraniotis, E. (2023). Assessing Students' Awareness of 4Cs Skills after Mobile-Technology-Supported Inquiry-Based Learning. *Sustainability (Switzerland)*, *15*(8). https://doi.org/10.3390/su15086725

Kurniawan, R. A., Rifa'i, M. R., & Fajar, D. M. (2020). Analisis Kemenarikan Media

Pembelajaran Phet Berbasis Virtual Lab pada Materi Listrik Statis Selama Perkuliahan Daring Ditinjau dari Perspektif Mahasiswa. *VEKTOR: Jurnal Pendidikan IPA*, *1*(1), 19–28. https://doi.org/10.35719/vektor.v1i1.6

Kusumawati, W., Kurniasari, N., & Khusniyah, Z. (2019). Pengaruh Integrasi Model Pembelajaran Siklus 5E Dengan Case Based Learning (CBL) Terhadap Kecenderungan Berpikir Kritis Mahasiswa. *Jurnal Edunursing*, *3*(1), 43–58.

Lesnowati, I., & Hafifi, H. (2021). Penerapan Model Pembelajaran Project Based Learning Untuk Meningkatkan Motivasi Belajar Ekonomi Pada Siswa Kelas X SMK. *Jurnal Inovasi Pendidikan Mh Thamrin*, *5*(2), 9–18. https://doi.org/10.37012/jipmht.v5i2.652

Li, Z., Zhou, M., & Lam, K. K. L. (2022). Dance in Zoom: Using video conferencing tools to develop students' 4C skills and self-efficacy during COVID-19. *Thinking Skills and Creativity*, *46*, 101102–101102. https://doi.org/10.1016/j.tsc.2022.101102

Magaña, M. A. R. (2023). Analysis of the Hybrid Adaptive Learning Model in Higher Education. *International Journal of Human Sciences Research*, *3*(38), 2–8. https://doi.org/10.22533/at.ed.5583382310109

Marwati, A., Wahyudin, A., Utomo, A. S., Iza, N., & Halwa, E. N. (2021). Mendukung Transformasi Digital Melalui Penyusunan Program Studi Software Engineering. *Jurnal Penelitian Dan Pengembangan Pendidikan*, *5*(3), 373. https://doi.org/10.23887/jppp.v5i3.39242

Meyer, J., Jansen, T., Schiller, R., Liebenow, L. W., Steinbach, M., Horbach, A., & Fleckenstein, J. (2024). Using LLMs to bring evidence-based feedback into the classroom: AI-generated feedback increases secondary students' text revision, motivation, and positive emotions. *Computers and Education: Artificial Intelligence*, *6*, 100199–100199. https://doi.org/10.1016/j.caeai.2023.100199

Mirata, V., Hirt, F. S., Bergamin, P., & Westhuizen, C. v. d. (2020). Challenges and Contexts in Establishing Adaptive Learning in Higher Education: Findings From a Delphi Study. *International Journal of Educational Technology in Higher Education*, *17*(1). https://doi.org/10.1186/s41239-020-00209-y

Mite, A. D., Eveline, S., & Situmorang, R. (2021). Catholic Religious Learning With the Project Based Learning (PjBL) Approach: Validity and Feasibility. *Journal of Education Research and Evaluation*, *5*(2), 185. https://doi.org/10.23887/jere.v5i2.32300

Oktariani, O., Febliza, A., & Fauziah, N. (2020). Keterampilan Berpikir Kritis Calon Guru Kimia sebagai Kesiapan Menghadapi Revolusi Industri 4.0. *Journal of Natural Science and Integration*, *3*(2), 114–114. https://doi.org/10.24014/jnsi.v3i2.8791

Pattipawaej, O. C., Setiawan, D., Desiani, A., Tallar, R. Y., & Rahmat, A. (2023). The Implementation of Merdeka Belajar Kampus Merdeka Through Adaptive Learning Program and Curriculum Development. *Kne Social Sciences*. https://doi.org/10.18502/kss.v8i9.13330

Pokhrel, S., & Chhetri, R. (2021). A Literature Review on Impact of COVID-19 Pandemic on Teaching and Learning. *Higher Education for the Future*, *8*(1), 133–141. https://doi.org/10.1177/2347631120983481

Pradanti, P., & Muqtada, Moh. R. (2023). Students' Perceptions on Learning, Motivation, and Performance Through Project-Based Learning: Undergraduate Students' Case. *Pythagoras Jurnal Program Studi Pendidikan Matematika*, *12*(1), 16–26. https://doi.org/10.33373/pythagoras.v12i1.5011

Rahman, A. A., Suherman, A., Susilawati, D., & Putra, G. P. (2020). RADEC (Reading, Answering, Demonstrating, Explaining, and Creating) in LMS to Teach Tennis without Field Practicing. *Universal Journal of Educational Research*, *8*(11), 5433–5442. https://doi.org/10.13189/ujer.2020.081146

Rahman, M. M. (2020). Impact of Digital Technology in Higher Education. *International Journal of Research in Business and Social Science (2147-4478)*, *9*(5), 318–325. https://doi.org/10.20525/ijrbs.v9i5.815

Rendón-Castrillón, L., Ramírez-Carmona, M., & Ocampo-López, C. (2023). Training strategies from the undergraduate degree in chemical engineering focused on bioprocesses using PBL in the last decade. *Education for Chemical Engineers*, *44*, 104–116. https://doi.org/10.1016/j.ece.2023.05.008

Reyes, C. T., Lawrie, G. A., Thompson, C. D., & Kyne, S. H. (2022). "Every little thing that could possibly be provided helps": Analysis of online first-year chemistry resources using the universal design for learning framework. *Chemistry Education Research and Practice*, *23*(2), 385–407. https://doi.org/10.1039/D1RP00171J

Saad, A., Elbashir, A., Abdou, R., Alkhair, S., Ali, R., Parangusan, H., Ahmad, Z., & Al-Thani, N. J. (2024). Exploring of the gender variations in 4Cs skills among primary students. *Thinking Skills and Creativity*, *52*, 101510–101510. https://doi.org/10.1016/j.tsc.2024.101510

Sa'adah, M. (2020). Studi Komparatif Reformasi Pendidikan Di Singapura Dan Indonesia. *Jurnal Pembangunan Pendidikan Fondasi Dan Aplikasi*, *7*(1), 70–79. https://doi.org/10.21831/jppfa.v7i1.25273

Sanzana, M. R., Abdulrazic, M. O. M., Wong, J. Y., Karunagharan, J. K., & Chia, J. (2024). Gamified virtual labs: Shifting from physical environments for low-risk interactive learning. *Journal of Applied Research in Higher Education*, *16*(1), 208–221. https://doi.org/10.1108/JARHE-09-2022-0281

Schaller, M. D., Gencheva, M., Gunther, M. R., & Weed, S. A. (2023). Training doctoral students in critical thinking and experimental design using problem-based learning. *BMC Medical Education*, *23*(1), 1–12. https://doi.org/10.1186/s12909-023-04569-7

Svensson, T., Wilk, J., & Gustafsson Åman, K. (2022). Information literacy skills and learning gaps– Students' experiences and teachers' perceptions in interdisciplinary environmental science. *Journal of Academic Librarianship*, *48*(1), 102465–102465. https://doi.org/10.1016/j.acalib.2021.102465

Tang, K. H. D. (2023). Student-Centered Approach in Teaching and Learning: What Does It Really Mean? *Acta Pedagogia Asiana*, *2*(2), 72–83. https://doi.org/10.53623/apga.v2i2.218

Tuncel, İ., & Bahtiyar, A. (2015). A Case Study on Constructivist Learning Environment in Content Knowledge Courses in Science Teaching. *Procedia - Social and Behavioral Sciences*, *174*, 3178–3185. https://doi.org/10.1016/j.sbspro.2015.01.1059

Usmeldi, U., & Amini, R. (2022). Creative Project-Based Learning Model to Increase Creativity of Vocational High School Students. *International Journal of Evaluation and Research in Education (Ijere)*, *11*(4), 2155. https://doi.org/10.11591/ijere.v11i4.21214

Wang, C., Li, Z., & Bonk, C. (2024). Understanding self-directed learning in AI-Assisted writing: A mixed methods study of postsecondary learners. *Computers and Education: Artificial Intelligence*, *6*, 100247–100247. https://doi.org/10.1016/j.caeai.2024.100247

Wati, D. S. S. (2023). Kebijakan Kurikulum Merdeka Belajar Di Perguruan Tinggi. *Journal of Education Research*, *4*(3), 1021–1030. https://doi.org/10.37985/jer.v4i3.248