AI-Professional Development Model for Chemistry Teacher: Artificial Intelligence in Chemistry Education

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Article Info	Abstract
	This study aimed to propose a Professional Development Model (PDM) for chemistry teachers to enhance their professional development in Artificial Intelligence (AI). The research group consisted of 17 chemistry teachers. The study was designed using a particular case study suitable for qualitative research methods. Document review, teacher interviews, and AI opinions were utilized to create the model. Data were analyzed using inductive content analysis. The document analysis emphasized the teachers' knowledge of various topics, such as AI knowledge, AI tools, AI skills, AI ethics, AI attitudes, and AI literacy, to enable them to incorporate AI into their lessons. It was also highlighted that teachers should acquire domain-specific knowledge, skills, and competencies in the areas where artificial intelligence will be integrated. When examining the recommendations of artificial intelligence (ChatGPT and Gemini), it was found that they addressed similar content to the information included in the document analysis. Furthermore, chemistry teachers' stated their deficiencies in AI literacy, AI competencies, and developing AI lesson plans. They also stated that AI applications could be included in various subjects such as organic chemistry, chemical experiments, and chemical reactions. Following the analysis of documents and teacher and AI opinions, a 10-step PDM has been proposed to enhance chemistry teachers' professional development in AI.

Introduction

Scientific and technological advancements impact many areas of our lives, from health to the economy (Yoo & Yi, 2022). One of the areas experiencing change is education. Countries are integrating technology into their education systems (Lu et al., 2022). Technology enriches education, making learning more effective and lasting. Enriching educational environments with technological advancements has also paved the way for the effective implementation of the education process (Yıldırım, 2023). Indeed, many countries have utilized various technological advancements such as augmented reality, machine learning, and virtual reality to enrich education. One of the technological advancements is the Al. Al systems, created by humans to fulfill specific tasks and constantly improve themselves with the knowledge they acquire, mimic humans (Kuleto et al., 2022).

With the emergence of AI tools, the expectations of countries from individuals have also changed. The most critical impact of this change started with ChatGPT and Gemini (Arman & Lamiyar, 2023). With the introduction of artificial intelligence into our lives, many artificial intelligence tools have entered our lives rapidly. ChatGPT is one of the AIs used in this process. Along with ChatGPT, different artificial intelligence tools, such as Gemini, have also been developed and started to be used (Rane et al., 2024). With these changes, countries have started integrating AI into educational environments to raise AI-literate individuals (Yau et al., 2023). Similarly, many institutions and researchers have conducted and continue to conduct studies on integrating AI into educational environments. As AI is a relatively new concept and has yet to be fully understood, there is no consensus on how AI should be integrated into the educational process (Sanusi et al., 2022). Although there is no consensus on the full integration of AI, there are efforts to integrate AI into the educational process. For example, the governments of China and the United States have initiated projects to integrate AI into school curricula by 2028 (Chiu & Chai, 2020). Similarly, Canada and South Korea are investing in AI for K-12 students (Asia Pacific Foundation of Canada Korea AI Ethics Association, 2021). These projects of the countries aim to raise AI literate individuals. AI literacy means that an individual knows AI, follows developments in AI, has AI skills, and applies AI-related knowledge in their lives. Therefore, countries emphasize AI literacy in students, necessitating its integration into education.

Teachers play a crucial role in education and are primarily responsible for integrating and implementing Al (Luckin et al., 2022). Teachers have primary responsibility for students' learning outcomes as they play a vital

role in motivating and preparing students for education (Gökdere & Çepni, 2003). Similarly, teachers are crucial in developing students' AI literacy (Casal-Otero et al., 2023). The vital role of teachers in the educational process underlines their critical role in implementing AI in classrooms (Long & Magerko, 2020). For example, South Korea has launched efforts to train 5000 teachers in AI literacy by 2024.

The high-quality professional development of teachers in AI is directly linked to students' achievement of high academic standards in AI. For instance, teachers' science and mathematics proficiency correlates with students' achievements in these fields (Hibpshman, 2007). Similarly, teachers' competencies in AI are directly related to students' achievement of desired qualifications in AI. Moreover, a teacher must know mathematical concepts and rules to teach mathematics effectively (Eckman et al., 2016). Teachers must also have sufficient knowledge and expertise in AI to effectively teach AI in their classrooms (Salas-Pilco et al., 2022). Therefore, there is a need for specially designed, robust pedagogical training in AI to ensure that teachers have the necessary knowledge and skills in AI because studies emphasize that teachers need more knowledge about AI (Lindner & Romeike, 2019).

Teachers' insufficient knowledge of AI leads to low performance in implementing AI in their classrooms (Park et al., 2023). Therefore, teachers must have sufficient knowledge of AI to effectively implement AI practices in their classrooms (Chounta et al., 2022). This is because teachers' mastery of the subjects they teach directly affects their self-efficacy in the teaching and learning process (Stohlmann et al., 2012). Self-efficacy refers to individuals' beliefs about what they can or cannot do in situations based on their knowledge, skills, and abilities (Bandura, 1997).

Self-efficacy beliefs are one of the significant factors influencing teachers' behaviors and activities in the classroom, classroom management, and instructional decisions, affecting the effectiveness and efficiency of teaching (Serin & Bayraktar, 2015). Self-efficacy belief motivates individuals to take action and guides them to achieve desired outcomes (Bandura, 1986). Therefore, the efforts exerted by teachers during the teaching-learning process significantly impact their beliefs about what they can achieve in the classroom (Bandura, 1997). Thus, teachers' low self-efficacy in AI can hinder effective teaching (Çelik, 2023). Indeed, the lack of sufficient AI knowledge among teachers can also lead to negative attitudes toward implementing AI in their classrooms (Park et al., 2023). Hence, teachers' knowledge, skills, and self-confidence are directly related to creating an effective learning environment for AI (Bandura, 1993). Therefore, it is necessary to develop high-quality AI PD programs for teachers to implement AI in classrooms (Park et al., 2023).

When the literature is examined, there needs to be more topics covered in AI PD programs for teachers and how to integrate these topics into their fields. In addition, more AI program units are required for classroom practice (Chiu et al., 2021). Moreover, few studies emphasize how to conduct subject-specific training processes on AI for teachers (Muslim al-Zyoud, 2020). Therefore, organizing AI training to meet the needs of teachers will facilitate the integration of AI into the educational process. Thus, in this study, a PDM for chemistry teachers was proposed. This is because, when the literature is examined, it is understood that there are insufficient PD programs for chemistry teachers related to AI. Despite insufficient programs, studies show the connection between AI and chemistry education and its use in chemistry teaching (Emenike & Emenike, 2023; Clark, 2023). Moreover, AI applications are accepted and used as a powerful tool in chemistry education (Choudhary et al., 2022). The fact that artificial intelligence is a powerful tool facilitates its application in chemistry (Owczarek, 2022).

The dominant role of AI in chemistry research and education (Choudhary et al., 2022) facilitates its connection to chemistry education topics. For example, Al helps to solve general chemistry problems (Daher et al., 2023). In addition, Al tools are used for visualizing molecules in chemistry education, conducting measurement and evaluation processes for chemistry courses, and preparing chemistry lesson plans (Clark, 2023; Emenike & Emenike, 2023; Joshi & Kumar, 2021). In addition, Al is used in various application processes such as molecular property prediction, drug discovery, nanotechnology, wastewater treatment, retrosynthesis, and reaction results in chemistry education (Clark, 2023).

In chemistry education, AI can be an assessment tool to provide feedback on students' achievements and make inferences about students (Emenike & Emenike, 2023). Although there are studies on using Al in chemistry education, its integration into chemistry education is not at the desired level (Deng et al., 2023). Therefore, there are calls to increase the use of AI in chemistry education due to the limited studies of AI in chemistry education (Yuriev et al., 2023). In addition, one of the reasons for the limited integration of AI in chemistry education is the insufficient knowledge of chemistry teachers in this field. Therefore, it is essential to provide chemistry teachers professional development on AI.

In this study, a PDM is proposed to enhance the professional development of chemistry teachers in AI. This model aims to provide professional development opportunities tailored explicitly to chemistry teachers in the field of AI. In this context, the research problem was defined as follows: "How should a professional development program be designed to enhance the professional development of chemistry teachers?". This study sought answers to the following subquestions:

RQ1: Which AI-related content has been mentioned in artificial intelligence studies on teachers?
RQ2: What are chemistry teachers' views on AI?
RQ3: How does artificial intelligence propose a model for teachers' PD related to AI?
RQ4: What are the opinions of experts and artificial intelligence about the model developed for teacher training?

Method

Research Design

A PDM was proposed to enhance chemistry teachers' PD in AI within the study's scope. To achieve this objective, the study was designed using a unique case study approach suitable for qualitative research methods. In case study research, various qualitative data collection tools are used simultaneously. This approach aims to provide a detailed and comprehensive understanding of a situation within its real-life context (Yin, 2017). Additionally, diversifying the data collection methods ensures that qualitative data mutually reinforce each other.

Study Group

Participants were recruited using purposive convenience sampling, a non-probability sampling method. This approach is advantageous as it enables researchers to focus their resources on specific subgroups or segments of the population that are of particular interest, making it both time- and cost-effective (Balcı, 2016). Accordingly, the study group consisted of 17 chemistry teachers. Table 1 shows their demographic characteristics.

Table 1. Demographic characteristics

Theme	Category	Codes	f
Sociodemographic characteristics	Gender	Woman	13
		Man	4
	Work experience (year)	1-10	10
		11-18	4
		≥ 21	3
	School type	Public	14
		Private	3
	Branch	Chemistry teachers	113

Model Development Process

The AI PDM for chemistry teachers was developed according to the ADDIE instructional design model (Dick & Carey, 1996). The ADDIE design model consists of five stages: Analysis, design, development, implementation, and evaluation. This model emerges as an instructional design model suitable for all types of instruction due to its essential nature, its inclusion of the components of other instructional design models, and its coverage of the basic definitions of instruction. For this reason, artificial intelligence professional development model for chemistry teachers was preferred. The development process of the AI PDM for Chemistry Teachers is detailed below.

Analysis Phase

In the AI PDM developed for chemistry teachers, (1) needs analysis, (2) participant analysis, (3) identification of the target group, (4) problem definition, and (5) task and instruction analysis stages were used. When the literature is examined, the lack of a study that emphasizes the content required for a professional development program aiming to develop chemistry teachers' artificial intelligence skills and the process of delivering such a

program reveals the importance of this study. Accordingly, a needs analysis was conducted to facilitate the development of chemistry teachers' artificial intelligence skills. Following the needs analysis, the research started with the question, "How should AI education for chemistry teachers be conducted?". To address this question, the instructional analysis process was initiated. In the process of instructional analysis, emphasis was placed on determining the content that should be taught to facilitate the PD of chemistry teachers on AI. Within the scope of the study, all these processes were integrated with a comprehensive perspective by combining the information obtained from the literature, teacher opinions, and inquiries about AI.

Design Phase

The teaching process for chemistry teachers was defined in the design phase of the AI PDM. Literature documents were analyzed to formulate the teaching process. For the documents used at this stage, the following stages were taken into consideration: (1) accessing the documents, (2) confirming the authenticity of the documents (these documents were analyzed both from the journals in which they were published and from the indexed pages), (3) understanding the documents, (4) analyzing the data, and (5) using the data (Yıldırım & Şimşek, 2011). After the literature review, AI's articles on teacher education were included in the process. Verification of the authenticity of the studies used in determining the teaching stages and content of AI is essential for the validity of the model. Therefore, the documents used in the study were analyzed through Web of Science, Scopus, Google Scholar, and Eric databases. The authenticity of the articles obtained through research was confirmed. Then, after the authenticity of the documents was confirmed, the stages and content were determined.

Development Phase

Following the document reviews, the emerged model underwent further refinement based on teacher feedback and the insights of AI tools. During this phase, the design was adjusted according to the feedback received from teachers, experts, and AI tools.

Implementation Phase

During this phase, a pilot study of the educational program designed for chemistry teachers was conducted with three teachers. This enabled testing the effectiveness of the proposed model.

Evaluation Phase

The final version of the developed model was evaluated after the pilot implementation in this phase.

Data Collection Tools

AI Interview Guide

This study utilized a semi-structured interview protocol to elicit chemistry teachers' perspectives on AI. The interview protocol was developed following a literature review, during which a pool of questions was generated. After creating the question pool, the interview protocol was evaluated by two different experts. One of the experts had publications on science education, while the other had publications on AI education. Based on the experts' feedback, adjustments were made to the interview protocol. Following these adjustments, a pilot study was conducted, and the final version of the interview protocol was established. As a result of these stages, the interview protocol comprised ten questions (See. Appendix).

Documents

The documents used in the study were investigated through the Web of Science, Scopus, Google Scholar, and Eric databases. The words "artificial intelligence," "teacher education," "PD," and "model" were searched for studies. In this direction, 19 studies were reached. Artificial intelligence studies conducted with teachers

between 2019 and 2024 were analyzed. As a result of the research, the journals in which the accessed articles were published and their originality were confirmed. Following the confirmation of the documents, the instructional stages and content of the model were examined and determined.

Data Analysis

The qualitative data obtained were analyzed using the inductive content analysis method. The data were collected through semi-structured interviews and documents. The analysis and interpretation of the data were conducted in four stages. These stages involved processing the data from documents, coding the data, organizing the codes, identifying the findings, and interpreting them (Yıldırım & Şimşek, 2012). Initially, two experts conducted separate analyses of the transcripts, independently identifying and elaborating on themes and codes. Following this, the themes and codes were structured and presented by the research inquiries. To guarantee coder consistency, two distinct professionals conducted individual coding sessions. The interrater reliability stood at 83%, signifying the reliability of the coding process. Then, the originality of the documents obtained was examined and confirmed. Similarly, two separate experts were involved in document reviews and conducted the coding. Along with coding qualitative data, the coding reliability was 82%. In determining the reliability value, changes were made to some codes. For example, 'Lesson plans' was changed to 'Al-lesson plans. Similarly, pedagogical knowledge was considered a province in 'Al pedagogical knowledge.' Subsequently, this code was treated separately as 'Al pedagogical knowledge and pedagogical' knowledge. Another example is related to the 'need' code. The 'needs' code was changed to 'Identification of needs. On the other hand, the study did not analyze Cohen's kappa value, because while calculating the Cohen Kappa value, not all of the codes are considered. For this reason, the reliability of all the codes was examined to reveal all of the codes in the article.

Reliability and Validity

Experts developed the codes and themes to minimize researcher bias and bolster internal validity. For data reliability, codes were devised based on input from an academic with publications in science education and one expert working in Al. These experts provided insights on the themes and codes, modifying non-common ones to avoid subjective judgments. Subsequently, two experts with publications in science education and AI reviewed and finalized the codes and themes. Interrater reliability was calculated using the formula [Reliability = (113) / (113+25)*100] suggested by Miles et al. (2014). Qualitative and quantitative approaches were employed to diversify data sources, significantly enhancing the validity and reliability of research findings. Finally, the relationships between the themes were identified, findings were defined and tabulated, and quotations about the codes were included to ensure internal reliability and eliminate bias. A similar process was conducted for the analysis of document reviews.

Findings

Themes, categories, and codes were presented in tables related to the research questions. Direct quotations were used to provide an accurate and coherent representation of participants' views and to facilitate readers' analysis and interpretation of the findings.

RQ1: Which AI-related content has been mentioned in AI studies on teachers?

In the first research question, studies on AI-related documents were examined, and the codes and contents obtained from the analyzed studies are presented in Table 2.

Table 2. Contents topics related to AI

No	Studies Study	Title	Content Related to AI and Supporting Elements
1.	Nyaaba & Zhaı, (2024)	Generative AI professional development needs for teacher education	AI knowledge Al tools Al ethical Al skills
2.	Nazaretsky et. al.	Teachers' trust in AI-powered	AI knowledge

	(2022)	educational technology and a Professional development program to improve it	Al tools AI attitude PK
3.	Çelik (2023)	Towards intelligence -TPACK: An empirical study on teachers' Professional knowledge to ethically integrate artificial intelligence (AI) based tools into education	AI technological knowledge AI pedagogical knowledge Al knowledge AI tools AI ethical PCK TPCAK
4.	Kuleto et. al. (2022)	The Attitudes of K-12 Schools' Teachers in Serbia towards the potential of Artificial Intelligence	Al knowledge AI tools Al lesson plans
5.	Lee et. al. (2024)	Artificial Intelligence (AI) Education for teaching in schools and their AI teacher training programs	Al skills Al tools Al knowledge AI pedagogical knowledge Practical knowledge Al attitude Al lesson plans
6.	Lindner & Romeike (2019)	Teachers' perspectives on artificial intelligence	Al knowledge Al attitude Al tools Al ethical Special content knowledge TPACK PK Practice examples, lack of adequate teaching material
7.	Chiu & Chai (2020)	Sustainable curriculum planning for artificial intelligence education: a self-determination theory perspective	Al-lesson plans Al knowledge Al tools Al ethical Al skills Al attitude Special content knowledge Pedagogical knowledge Limited resources Guided teacher Guide learned Teacher needs
8.	Sala-Pilco et. al. (2022)	Artificial intelligence and learning analytics in teacher education: A systematic review	Al ethical Al tools Al knowledge Al skills Special content knowledge Pedagogical knowledge Technical supports
9.	Zhou (2020)	Analysis of the professional development of teachers in the era of Artificial intelligence	Al skills Al knowledge Al Literacy Technological Knowledge
10.	Wardant et al. (2024)	Artificial intelligence in education: Mathematics teachers' perspectives, practices, and challenges	Al skills Al knowledge Al ethical Al pedagogical knowledge Pedagogical knowledge Special content knowledge Technical support

11.	Su et al. (2023)	Artificial intelligence (AI) literacy in early childhood education: the challenges and opportunities	Al-lesson plan Al literacy Al Attitude Al skills Al tools Al ethical Pedagogical knowledge TPACK Teacher/learning guided.
12.	Mondal et. al. (2023)	ChatGPT for Teachers: Practical examples for utilizing artificial intelligence for educational purposes	Al lesson plan PK Al knowledge Technical supports Resources
13.	Lin et. al. (2022)	Teachers' perceptions of teaching sustainable artificial intelligence: A design frame perspective	Al knowledge Al lesson plan Al practices Al ethical Pedagogical knowledge Special content knowledge Special context knowledge TPACK Al resources
14.	Yang (2022)	Artificial intelligence education for young children: Why, what, and how in curriculum design and implementation	Al literacy Al ethical Al attitude Al knowledge Al tools Learning goals Learning evaluation Teacher guided Al related activities Al activities
15.	Kitcharoen et al. (2024)	Enhancing teachers' Al competencies through Artificial Intelligence of things professional development training	Al literacy Al knowledge Al tools Al skills Al attitude Technological knowledge
16.	Kim & Kim (2022)	Teachers' perceptions of using an artificial intelligence based educational tool for scientific writing	Al attitude Al knowledge Al pedagogical knowledge Al tools
17.	Çelik et. al. (2022)	The promises and challenges of artificial intelligence for teachers: A Systematic review of research	Al skills Al knowledge Al attitude Al tools Al lesson plan Al ethical Pedagogical knowledge Special content knowledge Identification of needs Teacher needs Technical supports Teaching materials Using AI tools guided
18.	Kim et al. (2021)	Why and what to teach: Al curriculum for elementary school	Al knowledge Al skills Al attitude

			Al literacy
			Pedagogical knowledge
			AI lesson plan
			Guided teacher
19.	Park et. al. (2023)	Integrating artificial intelligence into science lessons: teachers' experiences and views	Al knowledge
			Al skills
			Al literacy
			AI-lesson plans
			Al technological knowledge
			Al pedagogical knowledge
			Al tools
			pedagogical knowledge
			Special content knowledge
			Teaching materials
			Resources activities

The results showed that AI studies on teachers focus on various topics such as AI knowledge, AI attitude, AI skills, AI ethics, AI tools, AI literacy, AI lesson plans, TPACK, PCK, domain-specific knowledge, and pedagogical knowledge. In addition, the documents highlight the need for various supporting elements, including teacher and student guides, AI tool usage guides, expert support, technical assistance, and others. These supporting elements are essential to make the educational process more effective.

RQ2: What are chemistry teachers' views on AI?

The first research question of the second subproblem addressed chemistry teachers' views on AI competencies (See Table 3). The results showed that most chemistry teachers need to be more adequately prepared regarding their AI competencies.

Table 3. Views on the Al competencies

Theme	Code
AI competencies	No (n=16)
	Yes (n=1)

The second research question of the second subproblem focused on chemistry teachers' perspectives regarding areas of deficiency in their AI competencies (See Table 4). The results showed that teachers mainly express feelings of inadequacy in their knowledge of AI, AI tools, and AI applications.

Table 4. Teachers' views on the areas of deficiency regarding AI competencies

Theme	Code
The areas of deficiency regarding Al competencies	AI knowledge (n=7)
	AI tools (n=5)
	AI applications (n=5)
	AI lesson plans (n=4)
	AI ethics (n=3)
	AI curriculum (n=3)
	Integration of AI into the lesson (n=2)

* Participants have provided multiple responses

The third research question of the second subproblem addressed participants' views of Al literacy. Table 5 shows the results. The results indicate that most chemistry teachers feel inadequate in AI literacy. On the other hand, another teacher feels competent. The fourth research question of the second subproblem addressed participants' views on developing AI-based chemistry lesson plans. Table 6 shows the results.

Table 5. Views on AI literacy

Theme	Code
AI literacy	No (n=16)
	Yes (n=1)

Table 6. Views on developing AI-based chemistry lesson plans

Theme	Code
Developing AI-based chemistry lesson plans	No (n=14)
	Yes (n=3)

The results showed that most teachers stated they did not feel adequate in preparing AL-based chemistry lesson plans. When asked about the reasons for their inability to prepare an AI-based chemistry lesson plan, they provided similar responses as those in Table 4. The fifth research question of the second subproblem addressed participants' concerns about the ethical dimension of using AI in chemistry classes. Table 7 shows the results.

Table 7. Views on concerns about Al's ethical

Theme	Code
Al Ethical	Yes (n=15)
	No (n=2)

The results showed that most chemistry teachers believe using AI in chemistry classes may raise ethical concerns. When asked about these ethical concerns, chemistry teachers provided their perspectives.
The sixth research question of the second subproblem addressed chemistry teachers' views on the ethical status of using AI in chemistry classes (See Table 8).

Table 8. Views on the ethical status of using AI

Theme	Code
The ethical status of using AI	Assignment/Research tasks (n=6)
	Loss of personal data (n=4)
	Lack of privacy (n=2)
	Using others' information (n=2)
	Misleading information (n=1)

The results showed that chemistry teachers have emphasized that using AI in chemistry classes may pose ethical issues such as assigning homework/research, losing personal data, and lacking privacy. The seventh research question of the second subproblem addressed participants' views of the benefits of using AI in chemistry classes for students. Table 9 shows the results. The findings show that most chemistry teachers believe integrating artificial intelligence into chemistry courses benefits students.

Tablo 9. Participants' views of the benefits of using AI in chemistry classes for students

Theme	Code
Benefits of using AI in chemistry classes for students	Yes (n=16)
	Not sure (n=1)

Participants who found AI useful in chemistry classes for students were asked what kind of benefits they thought AI had. Table 10 shows the results. The results showed that chemistry teachers believe integrating AI into lessons will enhance students' AI literacy, facilitate lasting learning, and encourage individualized learning.

Table 10. Participants' views of the benefits of using AI for students

Theme	Code
Benefits of using AI	AI literacy (n=10)
	Permanent learning (n=6)
	Individualized learning (n=5)
	Effective learning (n=4)
	Al skills (n=3)
	Creating their content (n=2)
	Feedback about lesson (n=1)

* Participants have provided multiple responses

The ninth research question of the second subproblem addressed the opinions of chemistry teachers on the connections between AI and chemistry topics (See Table 11).

Table 11. Views on the connection between AI and chemistry topics

Theme	Code
The connection between AI and Chemistry topics	Organic chemistry (n=6)
	Chemical reactions (n=5)
	Molecules and atoms (n=5)
	Chemistry experiments (n=4)
	Properties of matter (n=3)
	Periodic systems (n=2)
	Nanotechnology (n=1)

* Participants have provided multiple responses

The results show that teachers highlighted the connection between AI and chemistry, especially in organic chemistry, chemical reactions, molecules, and atoms. The tenth research question of the second subproblem addressed chemistry teachers' opinions on how AI could be customized for chemistry lessons (See Table 12). The results showed that chemistry teachers indicated that AI was used to customize chemistry concepts in various ways, such as visualizing, solving chemistry problems, analyzing chemical reactions, and conducting chemistry experiments.

Table 12. Views on customization of AI for chemistry lessons

Theme	Code
Customization of AI for chemistry lessons	Visualization of chemistry topics (n=12)
	Solving chemistry problems (n=9)
	Analyzing chemical reactions (n=9)
	Conducting chemistry experiments (n=8)
	Measurement and evaluation (n=5)
	Personalization of chemistry lessons (n=2)
	Predicting students' future in chemistry courses (n=1)
	Preparing appropriate lesson plans for chemistry lessons (n=1)

RQ3: How does artificial intelligence propose a teacher PD model related to AI?

For this research question, AI was asked two questions. In the first question, artificial intelligences were asked to suggest a professional development program for teachers. The professional development program proposed by the artificial intelligence and its content are presented in Figures 1, 2, 3, and 4.

Figure 1. PDM proposed by ChatGPT for teachers

AI for Teachers Professional Development Program Model
Program Goals
- To help teachers understand the basics of AI and its potential impact on education.
- To provide teachers with the skills and knowledge they need to use AI effectively in the classroom.
- To create a community of teachers who are committed to using AI to improve student learning.

Program Structure
The program will be delivered in a blended format, with online modules and in-person workshops. The online modules will provide teachers with the foundational knowledge they need to understand AI. The in-person workshops will provide teachers with the opportunity to learn how to use AI in the classroom and to collaborate with other teachers.

Program Content
The program will cover the following topics:
- **What is AI?**
- **The different types of AI**
- **The potential impact of AI on education**
- **How to use AI in the classroom**
- **Ethical considerations for using AI in education.**

Program Assessment
Teachers will be assessed on their understanding of the content and their ability to use AI in the classroom. Assessment will be conducted through a combination of online quizzes, in-person workshop activities, and a final project.

Program Dissemination
The program will be disseminated through a variety of channels, including:
- A website
- A social media campaign
- A series of webinars
- A national conference

Program Sustainability
The program will be sustained through a combination of funding sources, including:
- Government grants
- Corporate sponsorships
- Private donations

Program Impact
The program is expected to have a positive impact on teachers, students, and the education system as a whole. Teachers will gain the skills and knowledge they need to use AI effectively in the classroom. Students will benefit from learning with AI-powered tools and resources. The education system will become more innovative and efficient as a result of the program.

Conclusion
The AI for Teachers Professional Development Program Model is a comprehensive and innovative program that will help teachers understand and use AI to improve student learning. The program is designed to be accessible to teachers of all levels of experience and expertise. The program is also designed to be sustainable, so that it can continue to provide benefits to teachers and students for years to come.

Here are some additional resources that you may find helpful:
- The AI Index: https://aiindex.org/
- The Partnership on AI: https://www.partnershiponai.org/
- The AI for Education Initiative:

Figure 2. PDM Proposed by Gemini for teachers

When the PD programs related to artificial intelligence suggested by AIs are examined, it is understood that they propose similar models. However, the model offered by ChatGPT is more detailed than Gemini's. The topics AI tools express are identical to those found in the literature. ChatGPT and Gemini were also asked to suggest an AI PDM for chemistry teachers, as shown in Figures 3 and 4.

Title: Professional Development Program Model for Artificial Intelligence Education for Chemistry Teachers
Introduction: As artificial intelligence (AI) continues to revolutionize various fields, including chemistry, it becomes essential for chemistry teachers to stay updated with AI applications relevant to their subject. Integrating AI education into chemistry classrooms can enhance teaching methodologies, facilitate research, and deepen students' understanding of chemical concepts. This document presents a model for a professional development program specifically designed for chemistry teachers interested in integrating AI education into their teaching practices.

Program Goals:
1. Equip chemistry teachers with a foundational understanding of artificial intelligence concepts and their applications in chemistry.
2. Provide hands-on experience with AI tools and algorithms relevant to chemical data analysis, modeling, and simulations.
3. Enable teachers to develop AI-enhanced learning experiences and experiments tailored to chemistry curriculum objectives.
4. Foster collaboration and knowledge-sharing among chemistry educators interested in AI integration.
5. Promote ethical considerations and responsible use of AI technologies in chemistry education.

Program Components:
1. Fundamentals of AI in Chemistry:
   - Overview of artificial intelligence concepts, machine learning algorithms, and data analysis techniques relevant to chemistry.
   - Exploration of AI applications in chemical research, drug discovery, materials science, and computational chemistry.
   - Discussion of ethical considerations, data privacy, and bias in AI-driven chemical research.
2. AI Tools and Techniques for Chemical Data Analysis:
   - Hands-on training in using AI tools and software packages for chemical data preprocessing, feature selection, and predictive modeling.
   - Practical sessions on machine learning algorithms commonly used in chemistry, such as neural networks, decision trees, and support vector machines.
   - Case studies and real-world examples demonstrating the application of AI techniques in chemical data analysis and interpretation.
3. Integration of AI into Chemistry Curriculum:
   - Strategies for integrating AI concepts and tools into chemistry lesson plans, laboratory experiments, and research projects.
   - Development of AI-enhanced learning activities, simulations, and virtual experiments that align with chemistry curriculum standards.
   - Collaborative planning and sharing of AI-integrated teaching resources among participants.
4. Designing AI-Driven Chemistry Experiments:
   - Guidance on designing and conducting chemistry experiments enhanced by AI technologies, such as automated data collection and analysis systems.
   - Exploration of AI-driven approaches to chemical synthesis, reaction optimization, and materials discovery.
   - Incorporation of AI-based modeling and simulation tools for predicting chemical properties, reactions, and molecular structures.
5. Community Building and Networking:
   - Opportunities for chemistry teachers to connect with AI experts, computational chemists, and industry professionals.
   - Establishment of online forums, discussion groups, and professional networks focused on AI in chemistry education.
   - Collaboration on research projects, curriculum development initiatives, and grant opportunities related to AI integration.
6. Ethical Considerations and Best Practices:
   - Discussion of ethical guidelines, responsible conduct of research, and fair use of AI technologies in chemistry education.
   - Exploration of case studies and scenarios highlighting ethical dilemmas and considerations in AI-driven chemical research.
   - Development of strategies for teaching students about the ethical implications of AI applications in chemistry.
7. Evaluation and Reflection:
   - Assessment of teachers' learning outcomes and proficiency in AI concepts and techniques through formative and summative evaluations.
   - Reflection on the impact of AI integration on teaching practices, student engagement, and learning outcomes in chemistry classrooms.
   - Continuous feedback and program improvement based on participant input and evaluation findings.

Conclusion: By equipping chemistry teachers with the knowledge, skills, and resources to integrate artificial intelligence into their teaching practices, this professional development program aims to enhance the quality and relevance of chemistry education in the AI era. Through collaboration, experimentation, and ethical considerations, chemistry educators can leverage AI technologies to inspire curiosity, facilitate discovery, and prepare students for careers in chemistry and related fields.

Figure 3. PDM proposed by ChatGPT for chemistry teachers

Figure 4. PDM proposed by Gemini for chemistry teachers

When examining the PD programs suggested by ChatGPT and Gemini, it is evident that they emphasize the teaching of AI knowledge, pedagogical skills, hands-on activities and training, assessment and feedback, and support elements to enhance teachers' professional development. Additionally, it is noted that for a specific PD program tailored to chemistry teachers, in addition to the features proposed in the general PD program, it is necessary to address the integration of chemistry with AI and ethical issues. Furthermore, as part of this research question, ChatGPT and Gemini were questioned about the competencies teachers should possess in AI. The competencies suggested by ChatGPT and Gemini are presented in Figures 5, 6, 7, and 8.

Figure 5. The views of ChatGPT regarding the AI competencies

AI Competencies for Teachers
The rapid advancement of Artificial Intelligence (AI) has significant implications for the education sector. As AI becomes increasingly integrated into teaching and learning, it is crucial for teachers to possess the necessary competencies to effectively utilize this technology.
Here are some key AI competencies that teachers should develop:
1. Foundational Knowledge of AI:
- Understand the basics of AI, including its history, different types, and potential impact on education.
- Be familiar with the ethical considerations surrounding the use of AI in education.

2. AI Pedagogy:
- Understand how AI can be used to enhance student learning and engagement.
- Identify and select appropriate AI tools and resources for specific teaching and learning objectives.
- Effectively integrate AI into lesson plans and curriculum design.

3. AI Assessment:
- Understand how AI can be used to assess student learning and progress.
- Use AI-powered assessment tools to provide personalized feedback to students.

4. AI Technical Skills:
- Be able to use basic AI tools and applications.
- Have a basic understanding of AI programming languages and frameworks.
- Troubleshoot common technical issues related to AI in the classroom.

5. AI-related Learning Skills:
- Be able to learn and adapt to new AI technologies and tools.
- Encourage students to develop critical thinking and problem-solving skills related to AI.
- Promote responsible and ethical use of AI in the classroom.

6. Collaboration and Communication:
- Collaborate with other teachers, experts, and stakeholders to effectively integrate AI into the curriculum.
- Communicate effectively with students, parents, and the community about the benefits and risks of AI in education.

It is important to note that these competencies are not exhaustive and will continue to evolve as AI technology advances. However, by developing these core competencies, teachers can be well-positioned to leverage the power of AI to create a more personalized, engaging, and effective learning experience for all students.
Here are some additional resources that may be helpful for teachers who want to develop their AI competencies:
- **The AI Index:** https://aiiindex.org/
- **The Partnership on AI:** https://www.partnershiponai.org/
- **The AI for Education Initiative:**

By developing their AI competencies, teachers can ensure that they are prepared to use this powerful technology to its full potential in the classroom.

Figure 6. The views of Gemini regarding the AI competencies

ChatGPT has asked ChatGPT for the qualifications that chemistry teachers need regarding AI. Below is the response provided by ChatGPT.

Title: Essential Competencies for Chemistry Teachers in Artificial Intelligence Education
Introduction: As the integration of artificial intelligence (AI) into various scientific fields, including chemistry, becomes increasingly prevalent, it is imperative for chemistry teachers to possess specific competencies to effectively incorporate AI concepts into their teaching. This document outlines the key competencies that chemistry teachers should have in the realm of AI education.

1. Profound Understanding of Chemistry Concepts:
   - Mastery of fundamental principles, theories, and concepts in chemistry, including atomic structure, chemical bonding, kinetics, thermodynamics, and organic chemistry.
   - In-depth knowledge of key chemical processes, reactions, and phenomena across different branches of chemistry.

2. Foundation in Artificial Intelligence:
   - Familiarity with basic AI concepts, terminology, and applications relevant to chemistry, such as machine learning algorithms for chemical data analysis and modeling.
   - Understanding of AI-driven tools and techniques used in chemical research, drug discovery, materials science, and computational chemistry.

3. Integration of AI into Chemistry Curriculum:
   - Ability to identify opportunities for integrating AI concepts and tools into chemistry curriculum objectives, lesson plans, and laboratory experiments.
   - Skill in designing AI-enhanced learning experiences and projects that align with chemistry curriculum standards and foster student engagement and inquiry.

4. Computational Skills:
   - Proficiency in using computational tools and software for chemical data analysis, modeling, and simulation, such as molecular modeling software, quantum chemistry packages, and statistical analysis tools.
   - Experience in programming languages commonly used in chemistry and AI, such as Python, MATLAB, and R, for implementing AI algorithms and analyzing chemical data.

5. Critical Thinking and Problem-Solving:
   - Capacity to promote critical thinking skills and scientific inquiry among students through AI-driven problem-solving tasks and real-world applications in chemistry.
   - Skill in guiding students through the analysis, interpretation, and evaluation of AI-generated chemical data and predictions.

6. Ethical Considerations in AI-Driven Chemistry:
   - Awareness of ethical considerations, data privacy issues, and societal implications associated with the use of AI technologies in chemistry research and education.
   - Commitment to promoting responsible conduct of research, integrity, and ethical decision-making in AI-driven chemical investigations.

7. Collaboration and Professional Development:
   - Ability to collaborate with AI experts, computational chemists, and interdisciplinary teams to enhance AI education initiatives and advance chemical research.
   - Commitment to continuous professional development, staying updated with advancements in AI technologies and their applications in chemistry, and participating in relevant workshops, conferences, and professional networks.

Conclusion: Chemistry teachers play a pivotal role in preparing the next generation of scientists and innovators to navigate the intersection of chemistry and artificial intelligence. By possessing the competencies outlined above, educators can effectively integrate AI concepts into their chemistry classrooms, inspire students' curiosity and creativity, and empower them to leverage AI technologies for solving complex chemical problems and addressing societal challenges.

Figure 7. ChatGPT's views on the qualifications chemistry teachers need to have regarding AI

AI Competencies for Chemistry Teachers
In addition to the general AI competencies for teachers mentioned above, chemistry teachers need to develop specific competencies related to the application of AI in chemistry education. These competencies include:
1. **Knowledge of AI Applications in Chemistry:**
   - Understand the various ways AI can be used to enhance chemistry teaching and learning, including:
     - AI-powered tutoring systems for personalized learning
     - AI-based virtual labs for safe and controlled experimentation
     - AI-powered assessment tools for real-time feedback
     - AI-enabled simulations and visualizations for complex concepts
2. **Pedagogical Strategies for AI Integration:**
   - Develop effective strategies for integrating AI into chemistry lessons and curriculum, such as:
     - Flipped learning models with AI-based resources
     - Blended learning environments with AI-supported activities
     - Project-based learning with AI-enabled data analysis and visualization
3. **Assessment and Evaluation of AI-Enhanced Learning:**
   - Understand how to use AI to assess student learning and progress in chemistry, including:
     - AI-powered formative assessment tools for identifying learning gaps
     - AI-based adaptive learning systems for personalized learning paths
     - AI-enabled summative assessments for comprehensive evaluation
4. **Technical Skills for AI Implementation:**
   - Develop basic technical skills to use AI tools and resources in the chemistry classroom, such as:
     - Proficiency in using AI-based educational platforms
     - Ability to troubleshoot common technical issues
     - Familiarity with data management and analysis tools
5. **Ethical Considerations in AI Use:**
   - Understand the ethical implications of using AI in chemistry education, such as:
     - Data privacy and security concerns
     - Bias and fairness in AI algorithms
     - Transparency and accountability in AI-based decision making
6. **Collaboration and Professional Development:**
   - Collaborate with other chemistry teachers, experts, and stakeholders to effectively integrate AI into the curriculum.
   - Engage in professional development opportunities to stay up-to-date on the latest AI advancements and best practices in chemistry education.

By developing these competencies, chemistry teachers can effectively leverage AI to create a more engaging, personalized, and effective learning experience for their students.
Here are some additional resources that may be helpful for chemistry teachers who want to develop their AI competencies:
   - **The American Chemical Society:** https://www.acs.org/
   - **The National Science Teachers Association:** https://www.nsta.org/
   - **The Journal of Chemical Education:**

By developing their AI competencies, chemistry teachers can ensure that they are prepared to use this powerful technology to its full potential in the classroom.

Figure 8. Gemini's views on the qualifications chemistry teachers need to have regarding AI

When Figures 5, 6, 7, and 8 are examined, the titles suggested by ChatGPT and Gemini for PD programs are similar. Unlike PD programs, however, they focus on various AI-related skills, such as computational thinking, collaboration, communication, and learning skills.

RQ4: What are the opinions of experts and artificial intelligence about the model developed for teacher training?
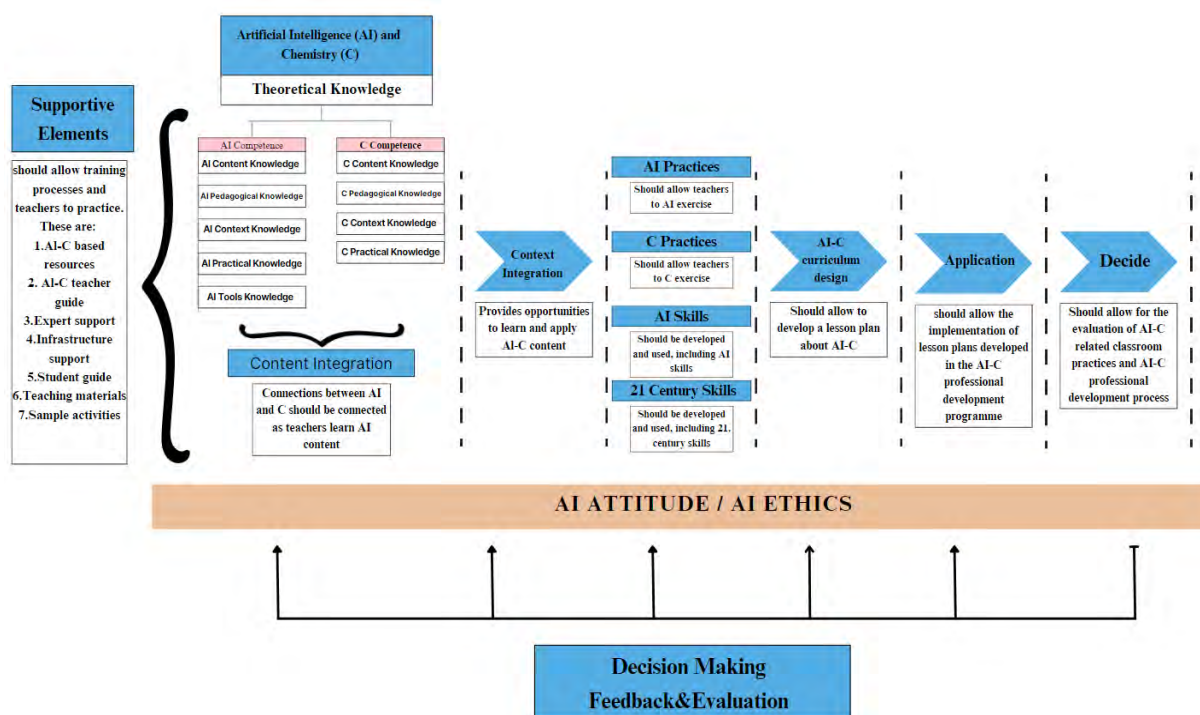

Figure 9. AI PDM for chemistry teachers

A PDM for chemistry teachers was developed based on document reviews, model proposals from AI, and teacher opinions. The model's first stage addresses teacher needs, while the second stage focuses on program objectives. The model presented below was formulated per identified needs and goals, considering input from experts and AI (Figure 9). AI was asked whether the model developed had any areas for improvement. ChatGPT was first asked about the model (Figure 9).

Here are my thoughts on the developed model:
The model encompasses several strengths:
1. Needs assessment for teachers: The initial phase involves identifying the specific needs of teachers, ensuring that the subsequent training is tailored to address these needs effectively.
2. Goal setting: By establishing clear objectives, the model provides direction and purpose to the educational process, ensuring that the outcomes are aligned with the intended goals.
3. Comprehensive content development: The inclusion of various aspects such as content knowledge, pedagogy, practical skills, tools, and contextual understanding ensures a well-rounded approach to content development, enhancing its effectiveness.
4. Integration of AI into daily life: Emphasizing the connection between AI content and everyday life through contextual understanding helps make the learning experience more relevant and relatable for teachers and students alike.
5. Focus on practical application and skill development: The model emphasizes not only the theoretical aspects but also the practical application of AI, along with the acquisition of specific skills and competencies, including 21st-century skills.
6. Systematic program design: The structured approach to designing AI programs, including the development of tailored lesson plans and program units, ensures coherence and alignment with educational objectives.
7. Feedback and evaluation: Incorporating feedback mechanisms and evaluation processes enables continuous improvement and ensures that decisions are informed by evidence and assessment data.

However, there are some areas where the model could be further enhanced:
1. Clarity on supportive elements: While the model mentions supportive elements such as equipment, resources, and expert support, providing more specific details on how these elements will be provided and utilized would enhance clarity and implementation.
2. Emphasis on AI ethics and attitudes: While the model acknowledges the importance of considering AI ethics and attitudes throughout the process, further emphasis and guidance on how to integrate these aspects into training and curriculum development would be beneficial.

Overall, the model provides a robust framework for integrating AI into education, but further refinement and clarity in certain areas would strengthen its effectiveness and implementation.

Figure 10. ChatGPT's views on the model

Detailed Thoughts on the Developed Model
Strengths of the Model:
- **Comprehensiveness:** The model comprehensively addresses the integration of AI into the teacher training program. Everything from the basics of AI to its integration into a specific field like chemistry has been considered.
- **Flexibility:** The model offers flexibility to be adapted to different fields and different levels of teachers.
- **Sustainability:** The supporting elements of the model will contribute to the long-term sustainability of the program.
- **Up-to-dateness:** The model is designed to be updated considering the ever-evolving nature of AI.
- **Feedback and Evaluation:** There are feedback and evaluation mechanisms at each stage of the model.
- **Supporting Elements:** Many supporting elements such as equipment, resources, expert, technical support, teacher and student guides, and sample activities will increase the success of the model.
- **Ethics and Attitude:** Considering AI ethics and attitude throughout the process is an important step.

Areas for Improvement:
- **Pilot Implementation:** A pilot implementation can be conducted to test the model's effectiveness in real life.
- **Stakeholder Involvement:** Teachers, experts, and other stakeholders can be involved more actively in the development and implementation of the model.
- **Implementation Phase:** It would be beneficial to plan the implementation phase in more detail and provide guidance to teachers.
- **Concrete Examples:** Concrete examples and case studies can be added for each stage of the model to ensure better understanding.

Detailed Review of the Model:
1. Needs Identification, Goal Setting, and Content Process:
- It is important to plan these stages in detail and determine concrete outputs for each stage.
- Examples of how AI can be used in different fields and at different levels can be added to the content process.
2. Contextual Information and Connection to Daily Life:
- Concrete examples and activities can be provided on how teachers can connect AI content to daily life.
3. AI Applications, Field-Specific Applications, and Skill Acquisition:
- Sample lesson plans and program units can be developed for AI applications in different fields and levels.
- Concrete activities and assessment tools can be provided for the acquisition of AI skills and 21st century skills.
4. AI Program Design:
- A detailed guide can be prepared for the development of AI and field-specific lesson plans and program units.
5. Implementation and Feedback:
- Mentoring and coaching support can be provided to teachers during the implementation phase.
- Feedback and evaluation mechanisms can be further detailed.
6. Decision Making and Supporting Elements:
- A clear framework can be created for the decisions to be made at each stage of the model.
- Detailed information can be provided on how and when the supporting elements will be used.

Overall Evaluation:
The developed AI teacher training program model is very comprehensive and detailed. The model has many strengths and potential. I believe that the model can be made even more effective and sustainable with some of the development suggestions mentioned above.
Congratulations on your model! I am sure it will help teachers discover the power of AI and use it to improve their students' learning.
Note: Please feel free to ask me any questions or feedback you have about your model.
Additional:
- Preparing a visual presentation of your model will help it to be better understood and disseminated.
- Translating your model into different languages can make it accessible to a wider range of teachers worldwide.
I hope this detailed evaluation is helpful for you.

Figure 11. Gemini's views on the model

The results showed that ChatGPT highlighted seven strengths of the developed model (Figure 10). Additionally, ChatGPT emphasized the need for (1) clearly defined support elements in the model and (2) comprehensive addressing of ethical and attitudinal aspects, along with strategies for cultivating such attitudes among teachers. In this context, the model's support elements were elucidated with explicit references to the literature. Subsequently, Gemini's perspectives on the model were obtained, and Gemini's responses are presented in Figure 11.

Gemini highlighted that the model developed for teachers has many strengths. Furthermore, Gemini emphasized that this model will provide robust learning experiences for teachers in AI. However, Gemini suggests that the model needs improvement in terms of (1) piloting, (2) stakeholder involvement, (3) implementation phase, and (4) providing concrete examples. In this context, based on the perspectives of both ChatGPT and Gemini, improvements were made to the model, sample content for chemistry courses was developed, and pilot implementations were conducted for chemistry teachers. Expert opinions regarding the model were also consulted within the scope of the study. Experts highlighted that the model has many strengths and will enhance teachers' competencies in AI. Additionally, experts emphasized that (1) the steps should be explained in detail, (2) examples related to the field should be provided, (3) pilot studies should be conducted, and (4) the decision-making mechanism should be clarified.

Discussion and Conclusion

The first research question of the study focused on analyzing studies related to artificial intelligence (AI) for teachers. The review results identified codes such as AI knowledge, AI attitude, AI skills, AI ethics, AI tools, AI literacy, AI lesson plans, TPACK, domain-specific knowledge, and pedagogical knowledge. When the identified codes are analyzed, it is understood that concepts are highlighted in teacher education literature. For example, Zhou (2020) focused on AI skills, AI knowledge, technology knowledge, and AI literacy. Similarly, Lee et al. (2024) highlighted AI skills, AI tools, AI knowledge, AI pedagogical knowledge, practical knowledge, AI attitude, and AI lesson plans. Many studies in the literature also emphasize similar issues related to AI (Lee et al., 2023; Lin et al., 2022; Mondal et al., 2023; Nazaretsky et al., 2022; Nyaaba & Zhai, 2024; Su et al., 2023; Wardant et al., 2024; Yang, 2022).

The second result obtained within the scope of the first research question is related to the supportive elements necessary for successfully implementing the AI process. It is emphasized that these supportive elements generally include teacher and student guides for AI, AI tool usage guides, expert support, technical support, and various other supports. Additionally, it is noted that sample lesson plans and activities should be available for teachers to implement AI in their classrooms. For example, Su et al. (2023) emphasized the importance of teacher and student guides. Similarly, Mondal et al. (2023) emphasized the importance of technical support and AI resources in the AI process. Linder and Romeike (2019) mentioned needing more application examples and sufficient materials in the AI process. In addition, many other studies emphasize the importance of similar supporting elements (Chiu & Chai, 2020; Salas-Pilco et al., 2022). Our result is consistent with the literature (Kim & Kim, 2022; Kitcharoen et al., 2024)).

Within the scope of the second sub-question, chemistry teachers' views on their competencies in AI were investigated. Most chemistry teachers feel they need to be more competent in AI. Moreover, chemistry teachers must improve AI knowledge, tools, applications, lesson planning, ethics, and course integration. In addition to this, teachers also feel they need to improve AI literacy. Similarly, they think they need to improve in developing AI-based lesson plans.

Furthermore, chemistry teachers have expressed ethical concerns about various aspects of artificial intelligence use, including assigning homework and research, personal data loss, privacy issues, using others' information, and the possibility of artificial intelligence misguidance. For instance, Park et al. (2023) study indicated that teachers must be more competent in artificial intelligence. Another study emphasized that insufficient support and resources related to artificial intelligence affect teachers' in-class applications (Lindner & Romeike, 2019). Çelik et al. (2022) study also highlighted that teachers want to use artificial intelligence in their classrooms. Our results are consistent with the literature.

Another result obtained within the scope of the study's second research question is examining teachers' views on the effects of using AI on students in chemistry classes. Teachers stated that using AI in chemistry classes provides various advantages, such as developing students' AI literacy, ensuring permanent learning, supporting individual learning, and promoting effective learning. These results are consistent with studies in the literature

(Kim et al., 2021). Additionally, Ng et al.'s (2022) study emphasized the importance of students' having AI literacy. Similarly, many countries support students' AI literacy by including AI in K-12 schools.

Another result obtained within the scope of the second research question is the teachers' views on the connections between AI and chemistry subjects. Teachers stated that AI can be associated with organic chemistry, chemical reactions, molecules and atoms, chemistry experiments, the periodic table, and nanotechnology. In addition, the teachers believed that AI could help visualize chemistry topics, solve chemistry problems, analyze chemical reactions, conduct chemistry experiments, evaluate and predict students' future in chemistry, and develop lesson plans. For example, Yuriev et al. (2023) highlighted the importance of artificial intelligence in chemistry education. Sarıoğlu (2023) highlighted that AI tools could be used to visualize molecules in measurement and evaluation processes in chemistry courses and the course planning process. Choudhary et al. (2022) stated that AI could be used in molecular property prediction, drug discovery, molecular design, nanotechnology, wastewater treatment, retrosynthesis, and reaction results. Clark (2023) highlighted its potential use in general chemistry laboratories and organic chemistry courses. The findings of this study are consistent with the conclusions of the literature.

Within the scope of the third problem of the research, the views of artificial intelligence on PD programs were examined. In addition to the information obtained from the document reviews, artificial intelligence stated that there is a need for information about AI, pedagogical knowledge, practical activities, and feedback to support teachers' PD programs. They also highlighted the need to emphasize integrating chemistry with AI, attitudes, and ethical issues in a PD program specific to chemistry teachers. The information provided by AI is in line with the documentation in the literature.

The fourth research question of the study explores the perspectives of experts and artificial intelligence on the model developed for chemistry teachers. ChatGPT highlighted both the strengths and weaknesses of the developed model for AI education, stressing the importance of clarity in support elements, ethics, and attitudes. Similarly, Gemini noted the model's strengths in supporting teachers' PD, emphasizing the significance of pilot implementation, providing support with concrete examples, the implementation phase, and conducting a pilot study. Experts also underscored the model's strengths in supporting teachers' PD. Additionally, they highlighted the necessity of explaining the model's steps, offering domain-specific examples, conducting pilot studies, and clarifying the decision-making mechanism. Based on the literature review, views on AI, and teacher views, a model was proposed to support chemistry teachers' professional development on AI.
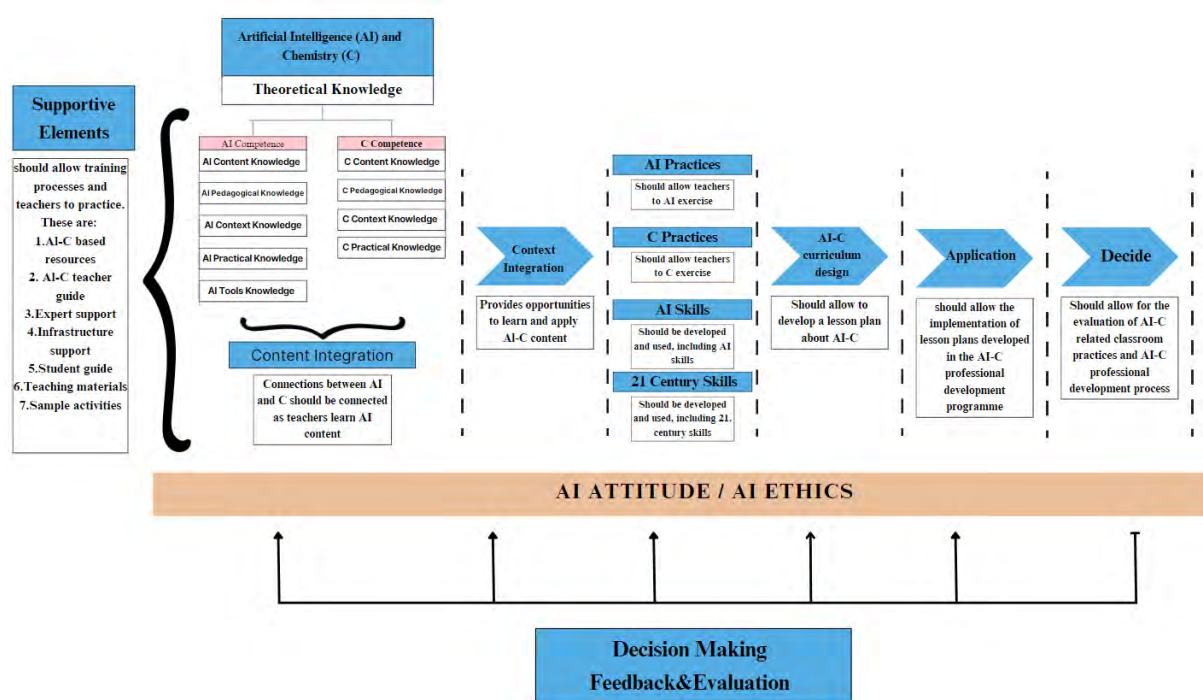
AI PDM for Chemistry Teachers

Figure 12. Proposed model for AI PDM for chemistry teachers

The stages and contents of the developed model are detailed below:

Identification of Teacher Needs: This stage involves identifying the expectations of chemistry teachers concerning AI to determine their training requirements about AI before the education process commences.

Determination of Objectives: This stage entails establishing the objectives expected to be accomplished in the AI professional development program for chemistry teachers.

AI and Chemistry Theoretical Knowledge: This stage involves providing teachers with knowledge about AI and the field of chemistry. It consists of two parts: (1) AI competencies and (2) chemistry-related competencies. AI competencies include AI-related domain, pedagogy, context, and application information that should be provided in teacher training. Competencies related to chemistry encompass domain-specific, pedagogical, contextual, and applied knowledge of chemistry. Essentially, this section forms the content knowledge.

Context Integration: This stage establishes the connection between AI training for chemistry teachers and the environment in which teachers provide education. In other words, it entails establishing the real-life connection of the AI-related knowledge acquired by chemistry teachers. Contextual knowledge is vital for AI training because it creates a connection between the field of chemistry and daily life. Additionally, it provides opportunities to learn AI content and apply it in real-life chemistry classes.

AI and Chemistry Practices: This stage enables the implementation of practices in real life that are relevant to AI and chemistry. These practices include information about the practical applications of AI in chemistry education in classroom settings.

AI and 21st-Century Skills: This stage encompasses the 21st-century skills that chemistry teachers need to acquire, along with AI skills.

AI-Chemistry Program Design: This involves developing lesson plans related to AI and chemistry. This stage is essential for including AI applications in chemistry education because it outlines when teachers will use AI in their lessons.

Implementation Phase: This is the stage where the lesson plans developed by chemistry teachers as part of the AI professional development program are implemented. During this stage, teachers can apply the knowledge they have acquired in their classrooms. Conducting in-class implementations is crucial for teachers to identify any shortcomings in their training. Successful implementation of in-class activities within the scope of their training indicates the program's effectiveness.

Decision Stage: This stage involves identifying any shortcomings in the professional development program provided to teachers. It aims to pinpoint which parts of the program are deficient or not functioning as intended, and improvements are made accordingly. Teachers' feedback is gathered, and the training process is evaluated. Regular input from chemistry teachers is solicited throughout this process, and assessments are conducted.

AI Attitude and AI Ethics: Although not explicitly outlined as stages in the developed model, AI attitude and AI ethics are two crucial factors influencing it. Improving teachers' attitudes towards AI is essential for integrating AI into classroom practices, affecting teachers' self-efficacy. AI ethics is a significant concern addressed by teachers and users, highlighting the importance of providing teachers with training to support their professional development.

Supporting Elements: These components are necessary for teachers to integrate AI practices into their classrooms. These include AI-based resources, AI teacher guides, AI subject matter expert support, AI infrastructure support, AI student guides, AI teaching materials, and sample activities. All these elements constitute the necessary support mechanisms for chemistry teachers to implement in their lessons.

Limitations of the Study

The study had three limitations. First, the sample consisted only of chemistry teachers interested in AI education, so the results cannot be generalized. Second, the developed model is based on the views of ChatGPT and Gemini artificial intelligence. Third, the model presented in this study focuses on providing professional

development in artificial intelligence, especially for chemistry teachers. Also, the processes provided in this model are specific to chemistry teachers.

Suggestions

The model developed for chemistry teachers in this study could be adapted for use by teachers in other subject areas. Longitudinal studies can be conducted to evaluate the long-term effects of this model on teachers. Training programs based on this model can increase teachers' competencies in artificial intelligence. Furthermore, the model proposed in this study is expected to provide a basic framework for future research in the field of AI.

Ethical Considerations

The data for this study were collected voluntarily from chemistry teachers. I am grateful to all the teachers who participated in this process.

Scientific Ethics Declaration

The authors declare that the scientific ethical and legal responsibility of this article published in JESEH journal belongs to the authors.

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Appendix: AI Interview Guide

Dear Teachers,

This interview guide has been designed to gather your perspectives on AI. Your input will be utilized solely for research purposes, and the collective responses will be evaluated. To ensure the reliability of this study, it is crucial that you candidly express your genuine opinions. Respond to each question; your participation is integral to this scientific inquiry. Your answers will be utilized exclusively for this research and will not be disclosed to others. Thank you for your valuable contribution to this study.

1. What do teachers think about the AI competencies?
2. What do teachers think about the areas of deficiency regarding AI competencies?
3. What do teachers think about AI literacy?
4. What do teachers think about developing AI-based chemistry lesson plans?
5. What do teachers think about the ethical concerns about AI?
6. What do teachers think about the ethical status of using AI?
7. What do teachers think about the benefits of using AI in chemistry classes for students?
8. What do teachers think about using AI for students?
9. What do teachers think about the connection between AI and Chemistry topics?
10. What do teachers think about customizing AI for chemistry lessons?