Cakrawala Pendidikan
Jurnal Ilmiah Pendidikan
Vol. 44 No. 2, June 2025, pp.358-377
https://journal.uny.ac.id/index.php/cp/issue/view/2904
DOI: https://doi.org/10.21831/cp.v44i2.79010

Enhancing pedagogical content knowledge of preservice science teacher students through the inquiry reflective teaching model

Susilowati[1]*, Suciati[1], Sulistyo Saputro[2] , Muzzazinah[2]
[1]Universitas Negeri Yogyakarta, Indonesia
[2]Universitas Sebelas Maret, Indonesia
*Corresponding Author: susilowati@uny.ac.id

ABSTRACT

Reflecting the substance of the Preservice science teachers must have the ability to teach science appropriately. This ability is related to pedagogical and content knowledge. Teaching with inquiry is important in the development process of teacher professionalism. This is an urgency for preservice science teacher students to be equipped with teaching skills inquiry and the ability to reflect in learning. This research aimed to analyze the validity and practicality of the developed Inquiry Reflective Teaching (IRT) model; and to find the effectiveness of the IRT model in improving PCK. This study used the Research and Development (R&D) method. The data collection techniques used were IRT model assessment, practicality questionnaire, and Pedagogical Content Knowledge test. The data were analyzed using quantitative and qualitative analysis techniques. Quantitative data analysis techniques were used to determine the validity and practicality categories of the IRT model. Qualitative data analysis techniques were utilized to analyze data in the form of suggestions from experts, practitioner lecturers, and preservice science teacher students. The results of this study showed that the validity assessment was in a 'very valid' category. Likewise, the results of the assessment of the practicality of the IRT model were categorized as 'very practical'. The IRT model can effectively improve the PCK of preservice science teachers.

Keywords: preservice science teacher, pedagogical content knowledge, inquiry reflective teaching model

Article history

Received:	*Revised:*	*Accepted:*	*Published:*
4 October 2024	*7 March 2025*	*5 April 2025*	*24 June 2025*

Citation (APA Style): Susilowati, S., Suciati, S., Saputro, S., & Muzzazinah, M. (2025). Enhancing pedagogical content knowledge of preservice science teacher students through the inquiry reflective teaching model. *Cakrawala Pendidikan: Jurnal Ilmiah Pendidikan*, *44*(2), 358-377 DOI: https://doi.org/10.21831/cp.v44i2.79010

INTRODUCTION

Global challenges such as climate change, environmental crises, energy crises, and population explosions necessitate a learning approach that integrates science and technology to address these issues (Kelley & Knowles, 2016). Science teachers have a central role that needs to be considered (La Velle, 2020). The development of holistic science knowledge becomes a matter of substance, considering integration of science material contains aspects not only of science content (physics, chemistry, and biology) but also its relationships with technology and design or engineering, which illustrates basic knowledge to solve problems that arise in society. In this case, a science teacher needs to be able to present a problem that arises in the community in the classroom and invite students to understand the integrity of the material in the problem, which is a step in solving the problem. These abilities are related to pedagogical and teacher-professional competencies.

In essence, preservice science teachers must have the ability to teach science appropriately. Science teachers must master the content being taught and how to teach it. This ability is related to pedagogical and content knowledge, which is referred to as Pedagogical Content Knowledge (PCK). PCK mastery for preservice science teachers becomes urgent based on the results of research to become an effective science teacher. Teachers must be confident in both science content knowledge of various disciplines (physics, life science, earth, and space), and PCK. Professional development activity should use a constructivist approach, in which teachers build their knowledge through their experiences.

Integrated science learning reflects the vision and ideas of reform and innovative pedagogy. An interdisciplinary science teacher preparation program is needed. It is confirmed that the transformation of the science curriculum emphasizes science as a whole rather than separate sciences, including biology, chemistry, and physics (Bell & Gilbert, 1996). Efforts to reform science learning can be carried out by adopting Next Generation Science Standards (NGSS) (Thompson & Emmer, 2019; Christian et al., 2021). The integrative nature of the NGSS presents unique challenges for science teachers. One of the main goals of the NGSS is the integration of engineering practice with science content cohesive within subjects (NGSS, 2013).

The Indonesian science curriculum in the 2013 Curriculum has focused on the achievement of integrated scientific knowledge. However, not all competencies are achieved by students in the curriculum. Moreover, in the learning practices, integrated science learning has not appeared yet. Teachers experience difficulties teaching science in an integrated manner due to partial education (chemistry, biology, physics). This is confirmed by the results of previous research that science teachers in junior high schools still lack teaching science in an integrated manner and direction on constructivist meaningful learning (Susilowati, 2015).

Teaching with inquiry is important in the development process of teachers' professionalism. In general, teaching scientific inquiry is a challenge for pre-service science teachers (Loughran, 2014; Schneider & Plasman, 2011). One obstacle in learning planning about scientific investigations is inadequate content knowledge. There is still little research done to analyze the difficulties faced by aspiring pre-service teachers and beginner science teachers that emerge during learning planning and difficulties in putting it into practice (Barendsen & Henze, 2019; Ruys et al., 2012).

Several studies show that reflection in general is an effective learning method to foster the development of pedagogical content knowledge of teachers (Aydin Ayhan, 2013; Capps & Crawford, 2013; Evens et al., 2018). From the perspective of learning theory, learning planning is imperative in teacher education (Stender et al., 2017). Based on previous research, the results of self-reflection carried out by science teachers showed that things that are the focus of teacher attention are generally on technical learning activities, student behavior, media, and dynamics of learning activities. Teachers have not reflected regularly, comprehensively, and in-depth on matters relating to the teaching profession as a teacher, and other supporting matters related to improving the quality of activities learning, for example by reflecting on whether a learning method is good or not or reflecting on essential (important) concepts from the subject matter (Nugraha et al., 2020). Teachers generally face difficulty dealing with when carrying out in-depth reflection because teachers have insufficient knowledge regarding the components that should be reflected and how exactly the reflection process itself is carried out. The research examines reflection after the teaching process is carried out (retrospective reflection). Little research has been carried out in reflection exploration before the teaching process (anticipative reflection).

In general, reflection can be done before, during, and after the teaching process. Preservice science teacher students need to be prepared to have the ability to teach. However, preservice science teacher students do not yet have the skills and experience in the practice of science teaching. To teach certain science content, content-specific pedagogic knowledge is needed. Thinking about how to prepare for teaching, anticipatory reflection is considered a core step in developing and improving the teaching competence of preservice teachers (Loughran & Hamilton, 2016). That matters because anticipatory reflection is an indispensable prerequisite for the automatic formation of action scripts that experienced teachers rely on in their teaching (Stender et al., 2017). This is an urgency for preservice science teacher students to be equipped with inquiry teaching skills and the ability to reflect on learning. This is in accordance with the nature of science that inquiry is a learning model that animates science teaching. To teach with the inquiry learning model, the teacher's ability in integrated pedagogy of PCK is needed. An inquiry-based integrated science teaching model is needed to carry out a reflective stage to facilitate the development of PCK for preservice science teacher students. This research focuses on validation, the practicality of the IRT model, and the effectiveness of the IRT model. The validity of the IRT model is reviewed from expert assessment. Meanwhile, the practicality of the IRT model is reviewed from the assessments of practitioner lecturers and preservice science teacher students. This research aims to produce an IRT model in teaching for preservice science teacher students. The research questions were formulated as follows: (1) What is the validity of the Inquiry Reflective Teaching (IRT) model to enhance Pedagogical Content Knowledge (PCK) of preservice science teacher students on the topic of environmentally friendly technology? (2) What is the practicality of the Inquiry Reflective Teaching (IRT) model to enhance Pedagogical Content Knowledge (PCK) of preservice science teacher-students on the topic of environmentally friendly technology? (3) How is the effectiveness of the Inquiry Reflective Teaching (IRT) model in enhancing Pedagogical Content Knowledge (PCK) of preservice science teacher students on the topic of environmentally friendly technology?

METHOD

This research used the Research and Development (R&D) method of the Borg and Gall model (1983). The research was carried out via several steps, i.e., research and information collecting, planning, developing a preliminary form of the product, preliminary field testing, main product revision, main field testing, operational product revision, operational field testing, final product revision, dissemination, and implementation. The IRT model development stage includes ten steps, where these steps are divided into four main steps, namely define, design, development, and dissemination. This research was limited to the IRT model design stage up to the main scale test of one class. The design of the IRT model is presented in Figure 1.

The first stage that has been carried out is conducting research and collecting information. The initial research was conducted by involving 30 preservice science teacher students as subjects. Data collection from students included data on the ability to design investigations, the ability to link integrated science concepts, and the ability to plan learning. Initial research was carried out to analyze the issue of content pedagogic capabilities in learning planning. Information was collected to examine the components of the inquiry model, reflective components, and PCK abilities. In the planning stage, the PCK indicators and components were formulated. The PCK indicator was used to plot grids and instruments. The components of the inquiry and reflective model were detailed to prepare a draft model to be developed. The components of the inquiry model were detailed into a theoretical framework, syntax, learning environment, and learning impact.

The next step was to design an IRT model and its supports, including lecture plans, teaching materials, and student worksheets. The products that have been developed were then validated and carried out by a Focus Group Discussion (FGD). The product was validated by seven experts in the field of science learning. Experts assessed the feasibility of the products. The FGD was carried out to provide suggestions and responses for product improvement. In the preliminary field-testing stage, the IRT model was assessed for its practicality by five lecturers and five science education students. After the revision (main product revision) was carried out based on the results of preliminary field testing, the next step was main field testing.

The IRT model was tested through the main field-testing stage. The IRT model testing was carried out on the School Science Study III course, which includes Environmentally Friendly Technology material. This material was chosen because, in addition to being interesting, it also has urgency for preservice science teacher students to master. Limited testing was carried out involving 10 teacher students in semester V of the 2021/2022 Academic Year in August 2023. The testing was carried out to determine the implementation of the IRT model and the effectiveness of the IRT model in improving PCK. The research design used the Pre-Experiment: One-Group Pretest-Postest Design in main field testing and the Nonequivalent Control Group Pretest-posttest Design in operational field testing. The test subjects were given learning using the IRT model. Before learning, a pretest was conducted to determine the initial PCK and a posttest to determine the PCK after learning using the IRT model.

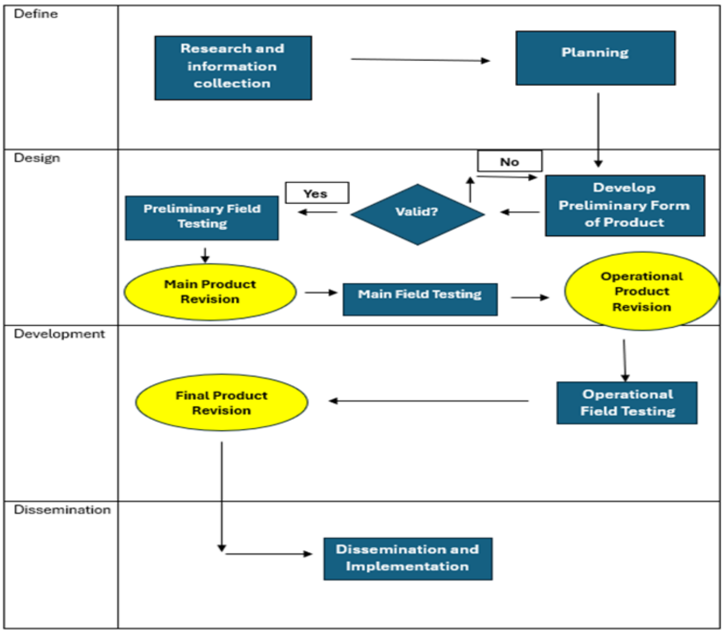

Figure 1. Research procedure

The research instruments used were an assessment sheet for the IRT model, a practicality assessment sheet for the model, a practicality questionnaire, and PCK test questions. The model assessment instruments were used by experts to validate the IRT model. The IRT model assessment components included the appropriateness of content, presentation, and language. Furthermore, the content appropriateness components were further divided into model components of theoretical basis, syntax, teacher and student behavior, class structure, learning environment, and class management. The practicality instruments were used by science education lecturers to assess the practicality of the model. Components in the practicality instrument of the IRT model consisted of the implementation of the IRT model syntax, including orientation, conceptualization, investigation, conclusion, discussion, problem suggestion, hypothesis, reasoning, and testing. Meanwhile, students filled out the questionnaire to provide feedback on the practicality of the IRT model that had been developed. The components of the IRT model practicality questionnaire for preservice science teacher students included aspects of ease of syntax and instructions in the IRT model (student activity sheet). The PCK test instrument is used to obtain PCK ability data before and after using the IRT model. In addition, the PCK test instrument is used to obtain PCK ability data in classes that use the IRT model and classes that do not use the usual model, namely inquiry.

The data analysis technique was carried out descriptively, quantitatively, and qualitatively. Quantitative descriptive analysis was used to analyze the data into descriptive parameters up to the product eligibility criteria. Qualitative data analysis was carried out to analyze data in the form of descriptions from validators regarding product improvement suggestions. Quantitative analysis uses prerequisite tests and hypothesis tests. The prerequisite tests used are normality and homogeneity tests. The difference tests used are the paired sample t-test and the independent sample t-test. Independent sample t-test analysis uses the Mann-Whitney test.

FINDINGS AND DISCUSSION

Findings

Define stage

At the define stage, initial research is carried out and information is collected regarding the abilities of preservice science teacher students in designing investigations. Data were obtained from an assessment of the investigation design. The data on the ability to design investigations illustrates the scientific method ability of preservice science teacher students. The data on the ability to design investigations were obtained through the assessment of the experimental design of preservice science teacher students in Semester V in the School Science Study III course at Universitas Negeri Yogyakarta. Furthermore, the analysis data on the ability to design investigations are presented in Table 1.

Table 1. Results of analysis of the ability of preservice science teacher students in designing investigations

No	Aspects of Designing Investigations	Percentage (%)
1.	Formulating the problem	52.50
2.	Defining variables	51.25
3.	Determining tools and materials	78.75
4.	Developing investigative steps	75.00
5.	Compiling a table of observation results	65.00

Based on Table 1, the data shows the ability to design investigations in the aspects of formulating problems is 52.5%, defining variables is 51.25%, determining tools and materials is 78.75%, compiling investigation steps is 75%, and compiling observation result tables is 65%. Based on the data, the ability to design investigations is still the lowest in the aspect of defining variables, and the highest is in the aspect of determining tools and materials. Meanwhile, the aspects of formulating problems, compiling investigation steps, and compiling observation results also show that they are still quite lacking. Furthermore, the final semester exam score data that depict the mastery of concepts of preservice science teacher students in the School Science Study III course at the Universitas Negeri Yogyakarta Science Education Study Program is presented in Figure 2.

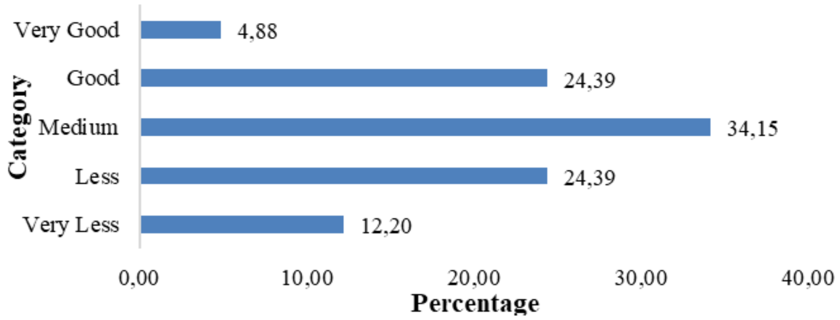

Figure 2. Results of analysis of the ability of preservice science teacher students in linking integrated science concepts

Based on Figure 2 shows the results of the ability of preservice science teacher students in linking integrated science concepts, including 4.88% in the very good category; 24.39% in the good category; 34.15% in the moderate category, 24.39% in the less category, and 12.20% in the very less category. It can be concluded that students tend to have difficulty linking one concept with the integrated science concept.

In the ability of preservice science teacher students in learning planning, the ability of each aspect of learning planning is presented in Table 2.

Table 2. Results of analysis of the ability of preservice science teachers in learning planning (RPP)

Aspect	Percentage (%)
Formulate indicators	35.90
Determine integration material	25.64
Determine model, approach, method	46.15
Determine media	15.38
Arranging learning activities	20.51
Determine the type of assessment	20.51

Based on Table 2, the percentage of each aspect of science learning planning is still low, namely formulating indicators at 35.90%; formulating integration materials at 25.64%; determining models, approaches, and methods at 46.15%; determining media of 15.38%; compiling learning activities of 20.51%; and determining the type of assessment of 20.51%. It can be concluded that the aspects of learning planning that are still lacking are determining media, compiling learning activities, determining the type of assessment, and determining integration materials. In addition, the ability to formulate indicators and determine models, approaches, and methods is also still lacking.

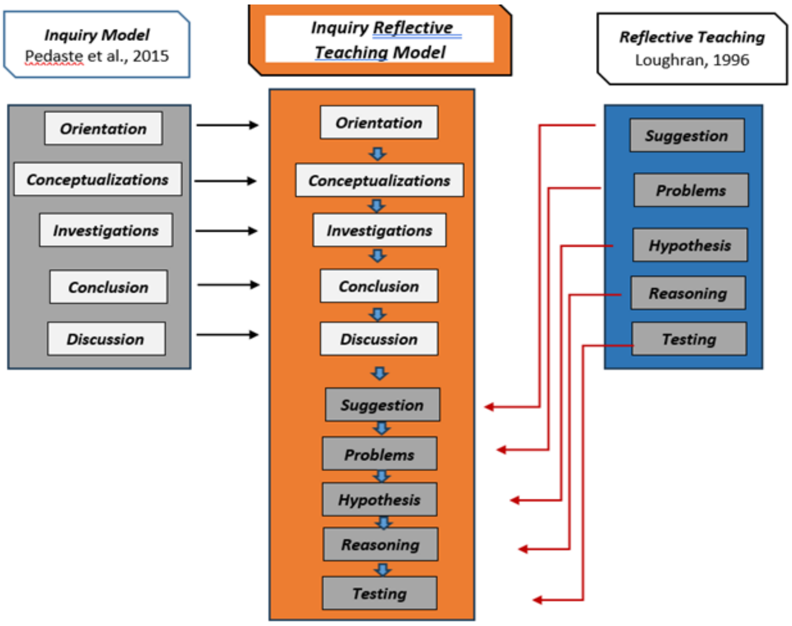

Figure 2. The IRT model design framework

Planning stage

After conducting a preliminary study, the next stage is the planning stage. The stages carried out in planning include: a. Formulate PCK indicators to plan grids and instruments. PCK components include Knowledge of Science Curriculum (KSC), Knowledge and beliefs about Students' Understanding of specific science topics (KSU), Knowledge and beliefs about assessment in science, Knowledge and beliefs about Instructional Strategies for teaching science (KIS); b. Combining the inquiry model and the reflective approach to produce a draft of the IRT model. The IRT model is a teaching or lecture model based on the inquiry teaching model integrated with reflective thinking in science learning planning. The inquiry teaching model includes orientations, conceptualization, investigation, conclusion, and discussion. The reflective process includes suggestions, problems, hypotheses, reasoning, and testing (Joyce et al., 2009; Pedaste et al., 2015; Loughran & Hamilton, 2016). Detailing the components of the IRT model into a theoretical framework, syntax, learning environment, and learning impact; c. Formulating the components of the developed learning model product in the form of RPS (Semester Learning Plan), model implementation guidebook, and Student Activity Sheet (LKM). The IRT model design framework is depicted in Figure 2.

Design stage

Develop a preliminary form of the product

The Develop Preliminary Form of Product stage includes the preparation of the product draft, FGD (Focus Group Discussion), and validation of the IRT model draft. At this stage, the IRT model design is carried out, which includes: 1) Model book design; and 2) Design of teaching materials and Student Activity Sheets.

Expert's validation

The IRT model product was validated by seven experts in science learning, science learning evaluation, PCK, and environmentally friendly technology materials. In addition to expert validation, FGD (Focus Group Discussion) was also conducted. FGD aims to obtain input and suggestions in depth regarding the contents of the developed model and then as revision material. In the validation process, an FGD is carried out and suggestions for improvements are obtained from experts, which are presented in Table 3. The results of the expert assessment analyzed by Aiken's validity are presented in Table 4.

Table 3. Results of the FGD (Focus Group Discussion)

Experts	Suggestion
Professor 1	Emphasize the scientific attitude dimensions of science and investigative skills.
Professor 2	Need to clarify the syntax of the findings.
Professor 3	Clarify how to reflect on learning from videos.
Professor 4	Clarify the integration of the developed models
Professor 5	Video selection for triggering reflection should be considered. It is necessary to choose videos whose learning content is not good so that it has the potential to give rise to many problems.
Doctor 1	The student worksheet orientation needed to be provided, so that students have critical discussions (pros and cons) regarding CO_2.
Doctor 2	It is necessary to pay attention to how to apply the right strategy according to the topic.

Table 4. The Aiken's V for each component of the IRT model

Components of the IRT Model Manual	Aiken's V	Validity
Introduction	0.91	Valid
Theoretical foundation	0.86	Valid
Syntax	0.92	Valid
Social system	0.88	Valid
Presentation	0.94	Valid

Based on Table 4, expert validation data was analyzed using the Aiken Coefficient (Aiken's V). The results of Aiken's V calculation were then compared with the criteria or minimum limit of the Aiken coefficient. The IRT model validation instrument used a scale of five and the number of experts (raters) was seven, thus obtaining a minimum limit of item validity of 0.82 (Aiken, 1985). Based on Aiken's V limit of 0.82, each component of the IRT model manual has 'valid' criteria.

Preliminary field testing

The IRT model manual that has been validated is then tested on limited sub-sectors (preliminary field testing). Limited testing is carried out on five student subjects and five practitioner lecturers. The practitioner lecturers are asked to pay close attention to the IRT model manual and then assess the practicality of the model manual. Students also looked at the model manual and then responded to a practicality questionnaire instrument. Suggestions from practitioner lecturers are used to improve the IRT model manual. The results of the practicality assessment by the lecturer are then analyzed for validity using Aiken validity and the results are presented in Table 5. By using Aiken's V standard of 0.80, the IRT model developed is declared valid. Questionnaire data from students are used to determine the practicality of the IRT model. The results of the analysis show that the average response from students is 4.32 and is included in the very practical category.

Table 5 shows that Aiken's value on all components is above 0.80; all components of the IRT model application are declared 'valid'. It can be concluded that the IRT learning model is 'practical' for use in classroom lectures. Besides, the results of student responses, with a total of five raters, have a range of answers on a scale of five. Based on the number of raters and the scale, the minimum limit of item validity is 0.8 (Aiken, 1985). In detail, the practicality of the IRT model is presented in Table 6. The table shows that the IRT model is 'practical' for use in lectures, even though there are some suggestions for improvement.

Table 5. Practical assessment of the IRT model manual from practitioner lecturers

IRT Model Components	Aiken's V	Criteria
Orientations	0.85	Valid
Conceptualization in questioning sub-syntax	0.90	Valid
Conceptualization in hypothesis generation sub-syntax	0.90	Valid
Investigation in exploration sub syntax	1	Valid
Investigation into experimenting with sub-syntax	0.80	Valid
Investigation of data interpretation sub-syntax	0.85	Valid
Conclusion	0.90	Valid
Discussion on communication sub-syntax	0.80	Valid
Discussion on reflection sub-syntax	0.80	Valid
Suggestion	0.85	Valid
Problem	0.85	Valid
Hypothesis generations	0.95	Valid
Reasoning	0.95	Valid
Testing	0.85	Valid
Presentation	0.85	Valid

Main product revision

The IRT model product resulting from the design is Draft I of the IRT Model. Furthermore, Draft I of the IRT model, which has been validated by experts, produces Draft II of the IRT model. Draft II of the IRT model is then tested for practicality by practicing lecturers and students. The results of improvements from practicing lecturers and students produce Draft III of the IRT model. Draft III is then used in the main field testing.

Table 6. The practicality of the IRT model from student response

IRT Model Components	Aiken's V	Criteria
Orientations	0.80	Practical
Conceptualization	0.76	Less practical
Investigation	0.79	Less practical
Conclusion	0.85	Practical
Discussion	0.81	Practical
Suggestion	0.75	Less practical
Problem	0.8	Practical
Hypothesis generations	0.77	Less practical
Reasoning	0.75	Less practical
Testing	0.82	Practical
Convenience	0.72	Less practical

Main field testing

Furthermore, Draft III of the IRT model was tested through the main field-testing stage. The test was conducted on the School Science Study III course, which includes Environmentally Friendly Technology material. This material was chosen because, in addition to being interesting, it also has urgency for preservice science teacher students to master. A limited test was conducted involving 10 students of Universitas Negeri Yogyakarta in semester V of the 2021/2022 Academic Year in August 2023. The trial was conducted to determine the implementation of the IRT model and the effectiveness of the IRT model in improving PCK.

The research design used at this stage is the Pre-Experiment: One-Group Pretest-Posttest Design. The test subjects were given learning using the IRT model. Before learning, a pretest was conducted to determine the initial PCK and a posttest was conducted to determine the PCK after learning using the IRT model.

Pretest and posttest data were analyzed using a paired sample t-test hypothesis test. Before the difference test, a prerequisite test was conducted, namely the normality test to determine whether the data were normally distributed. The results of the normality test using Shapiro-Wilk with samples below 100 are presented in Table 7.

Table 7. Data normality test results

	Shapiro Wilk		
	Statistic	Df	Sig.
Pre-test	0.848	10	0.055
Post-test	0.938	10	0.533

Table 7 shows that the pretest and posttest data are normally distributed, indicated by a significance value greater than or equal to 0.05. After the normal distribution is known, the next step is to test the pretest and posttest data using a paired sample t-test to determine whether the IRT model can empower the PCK of preservice science teacher students. The recapitulation of the results of the paired sample t-test hypothesis test is presented in Table 8.

Table 8. Paired sample T-test hypothesis test results

	Paired Differences							
	Mean	Std. Deviation	Std. Error Mean	Lower	Upper	T	Df	Sig. (one-tailed)
Pretest-posttest	-7.084	10.027	3.17	-14.25	0.89	-2.2	9	0.026

Table 8 enumerates the difference in the average pretest and posttest scores. The average pretest score is 49.58, and the average posttest score is 56.66 with Sig. Value (one-tailed) 0.026. As this study uses a one-way hypothesis, the Sig. Value (2-tailed) is divided by two; the result is 0.026, smaller than 0.05 (significance level 5%). This value suggests that the PCK of students after participating in learning with the IRT model is higher than before participating in learning with the IRT model.

Operational product revision

After the main scale model test, it continued with revision. Improvements were made to several parts, as shown in Table 9.

Table 9. Improvements to main field testing

No.	Revision
1.	Detailing the apperception steps in the lecture plan
2.	The time to direct students to formulate problems can be shortened so that not too much time is used.

Operational field testing

In the operational field-testing step, a product effectiveness test was conducted. This test was conducted to determine the effectiveness of the IRT model compared to the existing model, namely the inquiry model. At this stage, an expanded test was conducted involving 56 students in 2 study groups from Universitas Negeri Yogyakarta. The two classes were used as control and experimental classes. The research design used was Nonequivalent Control Group Pretest-posttest Design. Learning in the control class used Inquiry, where this learning is commonly used as the basis for developing the IRT model. While in the experimental class, the treatment was given with the developed IRT model. All classes were given a PCK pretest and posttest. The data from the control and experimental classes were then tested for hypotheses by conducting prerequisite tests for normality and homogeneity.

Operational field-testing data normality test

The normality test was conducted using Shapiro-Wilk, considering the number of samples below 100. All experimental and control class data in the form of pretest and posttest were tested for normality. The normality test results are presented in Table 10.

Table 10. Results of operational field-testing data normality test

Group	Shapiro-Wilk		
	Statistic	Df	Sig.
Experiment Pretest	0.936	28	0.085
Experiment Postest	0.960	28	0.353
Control Pretest	0.963	28	0.417
Control Postest	0.913	28	0.023

Based on Table 10, the significance value of the experiment pretest, experiment posttest, and control pretest is above 0.05, meaning the data is normally distributed. However, the posttest control data is not normally distributed.

Operational field-testing data homogeneity test

The homogeneity test is conducted to determine whether data from two or more groups come from populations that have the same variance (homogeneous). One way is to use the Levene test. If the significance of homogeneity is greater than 0.05 (sig>0.05), then the variables in both groups (experimental and control) are said to be homogeneous. The results of the homogeneity test are presented in Table 11.

Table 11. Results of operational field-testing data homogeneity test

		Levene Statistic	df1	df2	Sig.
Pedagogical Content Knowledge Test Result	Based on Mean	2.374	2	81	.100
	Based on Median	2.473	2	81	.091
	Based on the Median and with adjusted df	2.473	2	78.635	.091
	Based on trimmed mean	2.385	2	81	.099

Table 11 shows that the value of the significance based on the meaning is 0.100 which means it is greater than 0.05. This shows that both groups in the pretest and posttest data were declared through homogeneous Mann-Whitney Hypothesis testing.

After conducting prerequisite tests for both normality and homogeneity, the hypothesis test was conducted. The hypothesis test used the Mann-Whitney test because the experimental posttest and control posttest data had a non-normal distribution. The following are the hypotheses that were tested.

Ho: The PCK ability of prospective science teacher students who use the IRT model is not significantly different from the PCK ability in classes that use the inquiry model.

Ha: The PCK ability of prospective science teacher students who use the IRT model is significantly different from the PCK ability in classes that use the inquiry model.

The Mann-Whitney test was conducted on the pretest and posttest for the experimental and control groups. The results of the Mann-Whitney test with two groups, namely the experimental class and the control class, are presented in Table 12.

Table 12. Mann Whitney analysis results

Class	N	Mean
Posttest experiment	28	60.11
Posttest control	28	54.01
Asymp. Sig.	0.041	

Baed on Table 12, the significance value obtained is 0.041; this means that Ho is rejected, and Ha is accepted. It can be concluded that there is a significant difference between the experimental group and the control group.

Discussion

This study aims to find the feasibility, practicality, and effectiveness of the IRT (Inquiry Reflective Teaching) model that was developed. The IRT model has characteristics consisting of components including: (1) syntax or learning steps; (2) social system, namely the atmosphere and rules in learning; (3) principle of reaction, namely providing an overview of how to respond to students; (4) support system, namely facilities and infrastructure and learning environments that support the learning environment; (5) instructional and nurturant effects, namely the impact of learning that will be achieved and the accompanying impact after learning. The learning model is a description of a learning environment that includes teacher behavior when the model is applied (Joyce & Weil, 2009).

The IRT model is a teaching or lecture model based on the inquiry teaching model integrated with reflective thinking in planning science learning. The inquiry teaching model includes orientations, conceptualization, investigation, conclusion, and discussion. The reflective process includes suggestions, problems, hypotheses, reasoning, and testing (Joyce & Weil, 2009; Pedaste et al., 2015; Loughran, 1996). This model was developed to equip PCK (Pedagogical Content Knowledge) of preservice science teacher students. Based on the research results, explanations from the research results, and the IRT model development process carried out, the following results were obtained.

Eligibility of the model

The IRT model obtains feasibility with ‘valid’ criteria for all components and practicality in the very practical category. This model includes an introduction, theoretical basis, syntax, social system, and presentation. This model is adapted to the competencies of students as science teachers at the junior high school level. Preservice science teacher students must have the ability to teach science according to the nature of scientific knowledge and specific to certain content. This is in accordance with the essence of science, that science is rational knowledge about the universe and all its contents obtained through the scientific process. Koballa and Chiappetta (2010) define science as a way of thinking, as a way of investigating, and as a body of knowledge, and its interaction with technology and society. It can be concluded that in science, there are dimensions of ways of thinking, ways of investigation, building knowledge, and its relationship to technology and society. According to Sund and Trowbridge (1973), the word science is “both a body of knowledge and a process;” science is thus can be defined as building knowledge and processes.

Based on the content validity using Aiken's V, it was obtained that all components of the IRT model were declared ‘valid’ by experts. The Aiken’s V1 validity index value of each aspect is greater than the minimum value of the Aiken validity index of 0.79. Based on this assessment, it can be concluded that the IRT model has ‘valid’ criteria or is feasible to be implemented in learning. The developed IRT model is worthy of being reviewed from the components of the IRT model. The IRT model already contains components of the learning model in accordance with the model components according to Joyce & Weil (2009), including theoretical basis, objectives, syntax, and social system.

Practicality of the model

Practicality refers to the ease of the model to be used by the subject of study. This model is said to be practical if students and lecturers find it easy to use the IRT model in learning. The IRT model that has been approved by experts is then tested for practicality in a limited scope before this model is used. The subjects involved in the practicality test were five practicing lecturers and five student users. The results of the practicality test from the practicing lecturers showed that all model components had attained the ‘practical’ criteria. However, the practicality test from students showed that several model components had a level of practicality that was not yet optimal, including the conceptualization, investigation, and suggestion stages. In addition, the visual aspect (pictures) includes clarity of images, clarity of sentences, problem orientation, and completeness of student activity sheets. These deficiencies are the basis for improving the IRT model product. Likewise, the results of the practicality assessment from the practicing lecturers obtained suggestions for improvement including: (1) clarity of each syntax; (2) clarity of images; (3) implementation of the model; and learning steps in the learning implementation plan.

There are differences between the hypothetical model and the final IRT model. In the final IRT model, each syntax has been detailed to better guide students, including the syntax of problem orientation, formulating hypotheses, data interpretation, suggestions, problems, hypotheses, reasoning, and testing.

Effectiveness of the IRT model

Based on the difference test, there is a significant difference in the PCK ability of the control and experimental groups. The significance value is 0.041 (<0.05) so H0 is rejected, and Ha is accepted. It can be concluded that there is a significant difference between the experimental group and the control group. The average PCK ability of the experimental group is 60.11. The average control group is 54.01. The PCK ability of the experimental group using the IRT model is higher than that of the control group using the inquiry model. In terms of effect size, the magnitude of the effect of implementing the IRT model on Universitas Negeri Yogyakarta (UNY) students is 0.66, with a moderate category. Effect size categories include ≥ 0.8 with a large category; 0.3 ≤ x <0.8 with a medium category; and 0 <x<0.3 with a small category (Becker, 2000). This accentuates that the developed IRT model is effective in empowering the PCK of preservice science teacher students in the moderate category.

As the effectiveness of the IRT model is due to the syntax of the IRT model, the syntax of the IRT model can empower the PCK component. The syntax and activities of the IRT model are detailed in Table 14.

Table 14. Syntax and learning activities of the IRT model

Syntax	Subsyntax	Lecturer Activities	Student Activities
Problem Orientation		Guiding students to identify problems by presenting the phenomenon of fossil fuel energy scarcity through video.	Students watch a video about fossil fuel energy shortages and identify the problems.
Conceptualization	Formulating the Problem; Formulating a hypothesis	Guiding students to formulate problems based on the results of identifying the problem of fossil fuel scarcity.	Students formulate problems
Investigation	Exploration; Experimentation; Data interpretation	Guiding students in exploration, designing, conducting experiments, and data interpretation	Students explore, design, conduct experiments, interpret data
Conclusion		Guiding students to formulate conclusions	Students formulate conclusions
Discussion	Communication; Reflection	Guiding students in communicating results and reflecting on the investigation process	students in communicating results and reflecting on the investigation process
Suggestion		Guiding students to watch science learning videos in junior high school, providing ideas, thoughts, or suggestions.	Students watch science learning videos in junior high school and provide ideas, thoughts, or suggestions
Problems		Guide students to formulate problems from observed learning videos.	Students formulate problems from the learning videos they observe.
Hypothesis		Guiding students in formulating assumptions that contain efforts to improve the learning process	Students formulate assumptions containing efforts to improve the learning process.
Reasoning		Guiding students to reason or connect information, ideas, learning experiences	Guiding students to reason or connect information, ideas, learning experiences
Testing		Guiding students to conduct testing or take corrective action in the learning process by preparing lesson plans	Students carry out testing or take corrective action in the learning process by compiling lesson plans.

In the orientation syntax, a trigger is given for the phenomenon of energy scarcity and data on the increase in carbon dioxide. Next, students examine the case to find the problem. In this step, the process of analyzing material in the form of facts, and concepts that have been obtained appears. Analyzing material in the form of facts or concepts is one of the PCK indicators in the knowledge of science curriculum components. In the orientation stage, there is also the potential to develop knowledge and beliefs about students' understanding of specific science topics, namely analyzing difficult concepts that students understand. The relationship between the syntax of the IRT model and PCK empowerment is presented as follows.

In syntax conceptualization, students are encouraged to think about formulating problems and formulating hypotheses. In formulating problems, preservice science teacher students need to analyze materials in the form of facts, and concepts related to the problems presented. In this thinking process, preservice science teacher students also analyze concepts that are difficult to understand. The questioning and hypothesis generation steps encourage students to think about the steps that will be taken in answering the problem formulation. Thus, preservice science teacher students can relate to the methods that will be used in class when teaching environmentally friendly technology topic. The syntax of investigation includes the steps of exploration, investigation, and data interpretation. The exploration stage encourages preservice science teacher students to think about difficult concepts and then becomes the basis for consideration in determining student difficulties in the topic of environmentally friendly technology. The investigation sub-phase includes the stage of designing and conducting experiments. The investigation stage triggers preservice science teacher students to analyze facts and complex materials. In the activity of designing and conducting experiments, students think about problem-solving activities. This knowledge will then be used by preservice science teacher students in determining the learning activities that will be implemented, including strategies, models, approaches, and learning methods. This stage also directs to the analysis of the types of assessments that can be used in learning.

In the conclusion syntax, preservice science teacher students are involved in formulating experimental conclusions. In compiling conclusions, preservice science teacher students are encouraged to connect conclusions and problem formulations. In addition, this syntax also directs to analyze facts, and concepts of environmentally friendly technology and explores difficulties in the matrix. In the discussion syntax, students present the results of their investigations.

In the investigation of the topic of environmentally friendly technology, each group conducted experiments on environmentally friendly technology, including simple biogas and bioethanol experiments. One of the seven groups formulated the problem "How does the fermentation time of potato peel waste affect the quality of bioethanol?" In the syntax of the investigation, students designed an experiment with the following design.

Figure 5. Design of a simple bioethanol production tool from potato peel waste

Based on Figure 5, the steps taken are washing potato peel waste, drying, smoothing, fermentation, distillation, and flame testing. Based on the experiment, it was concluded that the length of fermentation of potato peel waste affects the quality of the bioethanol produced. The longer the fermentation is carried out, the better the quality of the bioethanol produced, as evidenced by the size of the flame produced.

After the syntax inquiry is carried out, the next activity is reflective teaching. In this step, students are encouraged to think reflectively about science learning using inquiry-based learning trigger videos. After watching the video, students are directed to enter the suggestion stage which contains the exploration of ideas, suggestions, or possibilities that arise in the mind based on the results of watching the learning video. The learning video contains science learning practices in schools. The next step is for students to find problems based on the overall picture of the science learning process video and experimental experiences. The next stage is formulating a hypothesis (hypothesis) for learning problem-solving. At this stage, students conduct a literature review (on books and research articles) as a basis for consideration for formulating a hypothesis in learning problem-solving. The next stage is reasoning. Students carry out the reasoning process, namely connecting information, ideas, and previous experiences to deepen the hypothesis. The last step of reflective teaching is testing. At this step, students carry out testing or actions that are manifested in the preparation of a learning plan. The learning implementation plan (RPP) or teaching module is then used for peer teaching. The syntax of suggestion, problems, hypothesis, reasoning, and testing encourages preservice science teacher students to have knowledge of the curriculum (knowledge of science curriculum), knowledge of students' understanding of specific science content, knowledge of strategies or methods (knowledge and beliefs about instructional strategies for teaching science), and knowledge of assessment (knowledge and belief about assessment in science).

Professional development of preservice science teachers

The teaching program for preservice science teachers focuses on the inquiry model to train high-level thinking skills as 21st-century skills (Treagust et al., 2015). The science teacher candidate development program emphasizes inquiry-based science learning as an effective “pedagogical tool” because it can encourage students to be more actively involved in the learning process (Eltanahy & Forawi, 2019). Professional development activities should use a constructivist approach where teachers build knowledge through experience. This constructivist approach can lead to sustainable changes in practical learning (Howes, 2002). The need for teachers to be skilled in pedagogy is needed to direct learners to provide authentic problem-solving experiences (Margot & Kettler, 2019). Science education is important in promoting a culture of scientific thinking and inspiring citizens to use evidence-based reasoning for decision-making (European Commission, 2015). Constructivist learning is an important foundation in the approach to science teacher development (Bell & Gilbert, 1996). Science teacher teaching programs in Indonesia need to apply knowledge to science teaching through investigation and inquiry (Rustaman, 2005). One of the main competencies of science teachers is to design and carry out experiments correctly (Permendiknas No. 16 of 2007 Academic Qualification Standards and Teacher Competencies).

The science teacher education program is directed at reflective teaching, a teaching program based on a scientific approach based on research findings and teaching records (Petersen & Treagust, 2014; Isozaki, 2018). Reflective teaching has several advantages. Several studies have shown that reflection is generally an effective learning method for fostering the development of teachers' pedagogical content knowledge (Capps & Crawford, 2013). Reflection is carried out not only after learning practices but also before learning practice activities (Loughran, 1996). Research reveals the benefits of reflective practices carried out by teachers, namely that teachers can find strengths and weaknesses and provide orientation for improving further learning. Teachers who reflect can ideally think deeply about every activity they do in the classroom with the aim of improvement and progress. Teachers who are not reflective often fail to recognize problems, have little desire to progress, and are not interested in achieving higher professional potential. The results of the study show that after reflecting, teachers can find strengths, weaknesses, and new ideas regarding good teaching methods (Nugraha et al., 2020).

Innovation in teaching preservice science teachers is directed at integrating science with an interdisciplinary approach, integrating content and pedagogy using themes (McKinnon et al., 2017). This is relevant to the statement (Kind & Chan, 2019) that preservice science teacher students should have pedagogical and content skills in teaching science. Effective science teachers must be confident in both science content knowledge of various disciplines (physics, life sciences, earth, and space) and also Pedagogical Content Knowledge (PCK) (Avery & Meyer, 2012). Integrated science learning reflects the vision and ideas of reform and pedagogical innovation. This is reinforced by the transformation of the science curriculum in emphasizing science as a whole rather than separate sciences between biology, chemistry, and physics (Bell & Gilbert, 1996). By 2021, 40 states have planned to adopt the Next Generation Science Standards (NGSS) to reform science instruction through improvements in teacher education, curriculum, and assessment (Thompson & Emmer, 2019; Christian et al., 2021). The integrative nature of the NGSS presents unique challenges for science teachers whose primary goal is to integrate engineering practices with science content cohesively across the subject area (NGSS, 2013).

Integrated science learning

In science learning at the junior high school level, science is presented in an integrated manner. Integrated science presents aspects of physics, chemistry, biology, earth science, astronomy, and other aspects of natural science. Integrated science is presented based on a contextual approach, namely connecting science with everyday life, is personal and direct, places one main idea, and contains problem-solving. In its presentation, science is presented with a unified concept (Hewitt et al., 2007). An integrated approach involves scientific processes, organizing principles, organizing natural integration of scientific knowledge, and its application in everyday life. Apart from that, in this integrated approach, students are also expected to be able to make connections in other fields including physics, astronomy, chemistry, geology, biology, technology, environment, health, and safety (Trefil & Robert, 2007). In an integrated model for understanding science around us, there are core concepts in terms of their relationship to physics, chemistry, biology, earth science, and astronomy (Tillery et al., 2007). Science contains three elements, namely body of knowledge, scientific inquiry, and Nature of Science (NoS). NoS is a characteristic of scientific knowledge that comes from formed knowledge, namely scientific inquiry (Lederman et al., 2019).

The transformation of the science curriculum emphasizes science as a whole rather than as separate subjects of biology, chemistry, and physics (Bell & Gilbert, 1996). Adoption of NGSS standards in science learning reform efforts can be done through improvements in teacher education, curriculum, and assessment (Thompson & Emmer, 2019; Christian et al., 2021)). The integrative nature of NGSS presents unique challenges for classroom teachers and teacher educators. One of the primary goals of the NGSS is the integration of engineering practice with science content in a cohesive manner within the course. This integration appears in aspects of main ideas from scientific disciplines, practical (inquiry), and cross-cutting concepts (concepts that have cross-field content) (NGSS, 2013). The idea of an integrated curriculum has been recognized as providing more informed, meaningful learning experiences that enhance conceptual understanding and application of knowledge (Harrell, 2010). Compared to other types of curriculum innovation, an integrated science curriculum reflects the vision and ideas of contemporary curriculum reform and learning innovation that includes considerations of social relevance, relevance to students' daily lives, integrated scientific knowledge from different fields or disciplines, and cooperative learning (National Research Council, 2013). However, this is contrary to the results of research where teachers experience difficulties due to partial educational backgrounds (chemistry, biology, physics) to be able to teach science in an integrated manner. This is confirmed by the results of previous research that science teachers in junior high schools are still lacking in teaching science in an integrated manner and are less focused on meaningful and constructivist learning (Susilowati, 2015; Vitasari et al., 2019).

This model is an integration between the inquiry model and the reflection approach. Inquiry is an essential model that science teachers need to master. Teaching with inquiry is important in the process of developing teacher professionalism (Earl et al., n.d.). Inquiry-based learning is an important way of teaching science that involves supporting students in investigating questions and using data as evidence to answer those questions (Capps & Crawford, 2013). Teaching through inquiry can promote scientific literacy and has the potential to increase students' understanding of science and engagement in science (Capps & Crawford, 2013). Sund and Trowbridge (1973) emphasize that discovery occurs when students use their mental processes to discover a concept or principle. At the higher education level, the level of inquiry is used, namely real-world applications (Wenning, 2010). At this level, students solve problems related to authentic situations when working individually or collaboratively in groups using problem and project-based approaches. The stages in real-world applications include: observation, manipulation, generalization, verification, and application (Wenning, 2010). The inquiry stage includes orientation; conceptualization (questioning and hypothesis generation); investigation (exploration, experimentation, and data interpretation); conclusion; and discussion (communication and reflection) (Pedaste et al., 2015).

Findings show that most of the participating teachers have a limited view of inquiry-based learning and NoS. In general, this view is reflected in teaching practice (Capps & Crawford, 2013). Preservice science teachers tend to have difficulty with the meaning of key terms for scientific inquiry, such as hypothesis or experiment, and tend to make errors in planning and implementing experiments (Gyllenpalm & Wickman, 2011; Windschitl, 2004). Several studies have also shown that there is a relationship between the abilities of pre-service science teachers and students' preconceptions and difficulties in scientific inquiry (Carey et al., 1989; Hammann et al., 2008). Teacher professional development should begin early in pre-service teacher education with authentic inquiry experiences (Capps & Crawford, 2013). Inquiry-based learning and teaching about the NoS are important components of science teaching reform in the United States (Capps & Crawford, 2013).

Teachers' weaknesses in inquiry can be strengthened with reflection-based teaching. Reflection can be done before, during, and after a teaching experience. Each type of reflection is adapted to varying situations or problems. Anticipatory reflection is a way to assess or frame a problem situation before action. This is an opportunity to prepare, to consciously and carefully anticipate an action that will be tested. Contextual factors that may influence this reflection (e.g.: content knowledge, age of students, previous experience with the same subject in the student group, and the degree of uncertainty in the outcome that the teacher is prepared to take risks on) will vary (Loughran, 1996). Retrospective reflection is a reflection by looking back at an experience, offering an opportunity to better understand previous experiences, and developing a new or deeper understanding of the situation (Loughran, 1996). Reflective practice as a habitual practice is recognized by many researchers as an essential activity for teachers and teacher educators (Earl et al., n.d.). This study applies anticipatory reflection where reflection practices are carried out as a basis for planning learning. Preservice science teacher students observe videos of science learning in junior high schools and then find problems that can be solved.

Reflective teaching is teaching in which there is a process that can be applied in confusing situations to help learners better understand the information available and allows teachers to guide and direct learning in an appropriate way. The value of reflection in teaching and learning is that it encourages one to see problems from different perspectives (Loughran, 1996). When learners actively reflect, it can encourage the development of a better understanding of the content of the subject matter and the inquiry process itself (Verawati et al., 2021). Through the habit of reflective practice and inquiry, a teacher will explore the strengths to change the way of teaching and learning better (Wolf, 2007). Teacher reflection has a positive effect on instructional planning and inquiry brings teachers to the basics of teaching (Vujaklija, 2021). Reflective teaching has the advantage that preservice science teachers can build arguments that describe the strengths and weaknesses of preservice teachers in teaching to lead to appropriate learning strategies (Loughran et al., 2004). Reflective teaching is also effective in fostering the development of teachers' pedagogical content knowledge (Capps & Crawford, 2013; Evens et al., 2018). Reflective practice has become an important aspect in determining good teaching and learning practices as an important part of professional practice and professional improvement (Yanuarti & Treagust, 2016).

This model was developed to empower the PCK of preservice science teacher students. PCK is defined as personal knowledge that is different from the general knowledge used at the beginning of the model. Second, PCK is defined as a specific context, namely teaching certain topics in a certain way for certain purposes to certain students. PCK cannot be generalized but exists in specific experiences. PCK is the application of knowledge to teaching. PCK can be found in the learning plans made by teachers and the reasons underlying decisions in learning. Third, PCK has a relationship with skills. The original conception of PCK emphasizes the knowledge that teachers describe and convey in their teaching. Furthermore, PCK develops to include the context of interaction in the classroom which develops between what teachers know and what teachers can do (Berry et al., 2015). PCK is a foundation of knowledge and skills by recognizing the use of knowledge during and around learning related to specific topics, students, and contexts (Gess-newsome, 2013). PCK is a concept for understanding effective science teaching. PCK is a very complex cognitive activity where teachers must apply knowledge from many domains. PCK also describes the teacher's understanding of how to help students understand specific material (Magnusson et al., 2006). Mastering the content of the material alone is not enough to teach integrated science well. Various theoretical works (Van Driel & Berry, 2012) and large-scale empirical studies (Voss & Kunter, 2020; Schmelzing et al., 2013)) have highlighted the importance of teachers' professional knowledge for the quality of classroom teaching and student learning success. Teacher knowledge and teachers' ability to consider the learning process are key components of teacher professional knowledge (Voss & Kunter, 2020). Thus, prospective science teachers should have pedagogical and content skills in teaching science (Kind & Chan, 2019).

The IRT model has been proven to improve the PCK of preservice science teachers and students. This model has two main steps, namely inquiry and reflection. Reflection has long been considered the basis for developing Pedagogical Content Knowledge (Forsler et al., 2023). Reflection using video "tools" or video-based reflection has been carried out in previous studies (Coffey, 2014; Hawkins & Park Rogers, 2016). However, in this study, reflection was combined sequentially with the inquiry model through the sequenced model integration model (Fogarty, 2009). Preservice science teachers need to understand the nature of science (concepts, science processes, attitudes) before learning planning, which is a pedagogical aspect. The science process is carried out through inquiry to find scientific concepts. In the inquiry process, scientific attitude aspects can also develop. This finding also strengthens the fact that preservice science teacher students should have pedagogical and content skills in teaching science (Shulman, 1986; Kind & Chan, 2019).

CONCLUSION

The IRT model has been developed consisting of a theoretical framework, syntax, learning environment, and learning impact components. The IRT model syntax includes orientations, conceptualization, investigation, conclusion, discussion, problem, suggestion, hypothesis, reasoning, and testing. The developed IRT model has ‘valid’ and ‘practical’ criteria for empowering PCK of preservice science teacher students. The IRT model can effectively improve the PCK of preservice science teacher students.

REFERENCES

Aiken, L. R. (1985). Three coefficients for analyzing the reliability and validity of ratings. *Educational and Psychological Measurement, 45*(1), 131–142. https://doi.org/10.1177/00131644854 51012

Avery, L. M., & Meyer, D. Z. (2012). Teaching science as science is practiced: opportunities and limits for enhancing preservice elementary teachers’ self-efficacy for science and science teaching.

Aydin Ayhan. (2013). The effect of school principals’ leadership styles on teachers’ organizational commitment and job satisfaction. *Educational Sciences: Theory & Practice*.

Barendsen, E., & Henze, I. (2019). Relating teacher pck and teacher practice using classroom observation. *Research in Science Education*, *49*(5), 1141–1175. https://doi.org/10.1007/s11165-017-9637-z

Becker, L. A. (2000). *Effect size* (ES). http://web.uccs.edu/lbecker/Psy590/es.htm
Bell, B. & Gilbert, J. (1996). *Teacher development: a model from science education*. Falmer Press.
Berry, A., Friedrichsen, P., & Loughran, J. (2015). *Re-examining pedagogical content knowledge in*. Taylor & Francis.
Borg, W. R. & M. D. Gall. (1989). *Educational research: An introduction*. fifth edition. Longman.
Capps, D. K., & Crawford, B. A. (2013). Inquiry-based professional development: What does it take to support teachers in learning about inquiry and nature of science? *International Journal of Science Education*, *35*(12), 1947–1978. https://doi.org/10.1080/09500693.2012.760209
Carey, S., Evans, R., Honda, M., Jay, E., & Unger, C. (1989). 'An experiment is when you try it and see if it works': A study of grade 7 students' understanding of the construction of scientific knowledge. *International Journal of Science Education*, *11*(5), 514–529. https://doi.org/10.1080/0950069890110504
Christian, K. B., Kelly, A. M., & Bugallo, M. F. (2021). NGSS-based teacher professional development to implement engineering practices in STEM instruction. *International Journal of STEM Education*, *8*(1), 1–18. https://doi.org/10.1186/s40594-021-00284-1
Coffey, A. M. (2014). Using video to develop skills in reflection in teacher education students. *Australian Journal of Teacher Education*, *39*(9), 86–97. https://doi.org/10.14221/ajte.2014v39n9.7
Earl, K., Ussher, B., Calder, N., Cowie, B., Hunter, P., Mills, J., Murphy, C., Petrie, K., & Swanson, C. (n.d.). *Editors special section: The sigmoid curve rosemary hipkins and bronwen cowie general section editorial board contact details about the journal notes for contributors*. http://www.crossref.org/
Eltanahy, M., & Forawi, S. (2019). Science teachers' and students' perceptions of the implementation of inquiry-based learning instruction in a middle school in Dubai. *Journal of Education*, *199*(1), 13–23. https://doi.org/10.1177/0022057419835791
Evens, M., Elen, J., Larmuseau, C., & Depaepe, F. (2018). Promoting the development of teacher professional knowledge: Integrating content and pedagogy in teacher education. *Teaching and Teacher Education*, *75*, 244–258. https://doi.org/10.1016/j.tate.2018.07.001
Fogarty, Robin. (2009). *How to integrate the curricula*. Skylight Publishing.
Forsler, A., Nilsson, P., & Walan, S. (2023). Capturing and developing teachers' pedagogical content knowledge in sustainable development using content representation and video-based reflection. *Research in Science Education*. https://doi.org/10.1007/s11165-023-10149-y
Gess-newsome, J. (2013). A report on the pck summit: current and future research directions history of research on effective teaching. *Inverness Research*
Gyllenpalm, J., & Wickman, P. O. (2011). The uses of the term hypothesis and the inquiry emphasis conflation in science teacher education. *International Journal of Science Education*, *33*(14), 1993–2015. https://doi.org/10.1080/09500693.2010.538938
Hammann, M., Phan, T. T. H., Ehmer, M., & Grimm, T. (2008). Assessing pupils' skills in experimentation. *Journal of Biological Education*, *42*(2), 66–72. https://doi.org/10.1080/00219266.2008.9656113
Harrell, P. E. (2010). Teaching an integrated science curriculum: linking teacher knowledge and teaching assignments. *Issues in Teacher Education*, *19*, 145-165
Hawkins, S., & Park Rogers, M. (2016). Tools for reflection: Video-based reflection within a preservice community of practice. *Journal of Science Teacher Education*, *27*(4), 415–437. https://doi.org/10.1007/s10972-016-9468-1
Hewitt, Paul G. (2007). *Conceptual integrated science*. Pearson Education.
Howes, E. V. (2002). Learning to teach science for all in the elementary grades: What do preservice teachers bring? *Journal of Research in Science Teaching*, *39*(9), 845–869. https://doi.org/10.1002/tea.10049

Isozaki, T. (2018). Science teacher education in Japan: past, present, and future. *Asia-Pacific Science Education*, *4*(10), 2–14. https://doi.org/https://doi.org/10.1186/s41029-018-0027-2

Joyce, Weil & Calhoun. (2009). *Model of teaching (Eighth Edition)*. Pearson Education.

Kelley, T. R., & Knowles, J. G. (2016). A conceptual framework for integrated STEM education. In *International Journal of STEM Education* (Vol. 3, Issue 1). Springer. https://doi.org/10.1186/s40594-016-0046-z

Kind, V., & Chan, K. K. H. (2019). Resolving the amalgam: connecting pedagogical content knowledge, content knowledge, and pedagogical knowledge. *International Journal of Science Education*, *41*(7), 964–978. https://doi.org/10.1080/09500693.2019.1584931

Koballa & Chiapetta. (2010). *Science instruction in the middle and secondary schools*. Pearson.

La Velle, L. (2020). The challenges for teacher education in the 21st century: urgency, complexity, and timeliness. In *Journal of Education for Teaching* (Vol. 46, Issue 1, pp. 1–3). Routledge. https://doi.org/10.1080/02607476.2019.1708621

Lederman, J., Lederman, N., Bartels, S., Jimenez, J., Akubo, M., Aly, S., Bao, C., Blanquet, E., Blonder, R., Bologna Soares de Andrade, M., Buntting, C., Cakir, M., EL-Deghaidy, H., ElZorkani, A., Gaigher, E., Guo, S., Hakanen, A., Hamed Al-Lal, S., Han-Tosunoglu, C., … Zhou, Q. (2019). An international collaborative investigation of beginning seventh grade students' understandings of scientific inquiry: Establishing a baseline. *Journal of Research in Science Teaching*, *56*(4), 486–515. https://doi.org/10.1002/tea.21512

Loughran, John. (1996). Developing reflective practice. *The Falmer Press.*

Loughran, J. (2014). Professionally developing as a teacher educator. *Journal of Teacher Education*, *65*(4), 271–283. https://doi.org/10.1177/0022487114533386

Loughran, J., & Hamilton, M. L. (2016). International handbook of teacher education. In *International Handbook of Teacher Education: Volume 1*. https://doi.org/10.1007/978-981-10-0366-0

Loughran, J., Mulhall, P., & Berry, A. (2004). In search of pedagogical content knowledge in science: Developing ways of articulating and documenting professional practice. *Journal of Research in Science Teaching*, *41*(4), 370–391. https://doi.org/10.1002/tea.20007

Magnusson, S., Krajcik, J., & Borko, H. (2006). Nature, sources, and development of pedagogical content knowledge for science teaching. *Examining Pedagogical Content Knowledge*, 95–132. https://doi.org/10.1007/0-306-47217-1_4

Margot, K. C., & Kettler, T. (2019). Teachers' perception of STEM integration and education: a systematic literature review. In *International Journal of STEM Education* (Vol. 6, Issue 1). https://doi.org/10.1186/s40594-018-0151-2

McKinnon, D. H., Danaia, L., & Deehan, J. (2017). The design of preservice primary teacher education science subjects: The emergence of an interactive educational design model. *Journal of Astronomy & Earth Sciences Education (JAESE)*, *4*(1), 1. https://doi.org/10.19030/jaese.v4i1.9972

National Research Council. (2013). Pedagogy of Science Part I. In *Science*.

NGSS. (2013). *Next generation science standard*. USA.

Nugraha, I., Widodo, A., & Riandi, R. (2020). Refleksi diri dan pengetahuan pedagogi konten guru biologi SMP melalui analisis rekaman video pembelajaran. *Jurnal Pendidikan Sains Indonesia*, *8*(1), 10–26. https://doi.org/10.24815/jpsi.v8i1.15317

Pedaste, M., Mäeots, M., Siiman, L. A., de Jong, T., van Riesen, S. A. N., Kamp, E. T., Manoli, C. C., Zacharia, Z. C., & Tsourlidaki, E. (2015). Phases of inquiry-based learning: Definitions and the inquiry cycle. *Educational Research Review*, *14*, 47–61. https://doi.org/10.1016/j.edurev.2015.02.003

Petersen, J. E., & Treagust, D. F. (2014). School and university partnerships: The role of teacher education institutions and primary schools in the development of preservice teachers' science teaching efficacy. *Australian Journal of Teacher Education*, *39*(9), 153–167. https://doi.org/10.14221/ajte.2014v39n9.2

Rustaman, N. Y. (2005). Perkembangan penelitian pembelajaran berbasis inkuiri dalam pendidikan sains. in makalah dipresentasikan dalam seminar nasional ii himpunan ikatan sarjada dan pemerhati pendidikan IPA Indonesia bekerjasama dengan FPMIPA. *Universitas Pendidikan Indonesia, Bandung* (pp. 22-23).

Ruys, I., van Keer, H., & Aelterman, A. (2012). Examining pre-service teacher competence in lesson planning pertaining to collaborative learning. *Journal of Curriculum Studies*, *44*(3), 349–379. https://doi.org/10.1080/00220272.2012.675355

Schneider, R. M., & Plasman, K. (2011). Science teacher learning progressions: A review of science teachers' pedagogical content knowledge development. In *Review of Educational Research* (Vol. 81, Issue 4, pp. 530–565). SAGE Publications Inc. https://doi.org/10.3102/0034654311423382

Stender, A., Brückmann, M., & Neumann, K. (2017). Transformation of topic-specific professional knowledge into personal pedagogical content knowledge through lesson planning. *International Journal of Science Education*, *39*(12), 1690–1714. https://doi.org/10.1080/09500693.2017.1351645

Sund and Trowbridge. (1967). *Teaching science by inquiry in the secondary school.* Charles E. Merrill Publishing Company.

Susilowati, P. H. (2015). Analisis Pedagogical Content Knowledge Guru IPA SMP Kelas Viii Dalam Implementasi Kurikulum 2013 Analysis of Pedagogical Content Knowledge Junior High School 8th Grade Science Teacher on Curriculum 2013 Implementation. In *Jurnal Pendidikan Matematika dan Sains Tahun III* (Issue 1).

Thompson, S. L., & Emmer, E. (2019). Closing the experience gap: The influence of an immersed methods course in science. *Journal of Science Teacher Education*, *30*(3), 300–319. https://doi.org/10.1080/1046560X.2018.1562811

Tillery, E. & Ross. (2007). *Integrated science*. McGraw Hill Companies.

Treagust, D. F., Won, M., & Petersen, J. (2015). Science teacher education in Australia: initiatives and challenges to improve the quality of teaching. 81–98. https://doi.org/10.1007/s10972-014-9410-3

Trefil, J. & Robert, H. (2007). The Sciences, an integrated approach. *John Wiley and Sons, Inc*.

Van Driel, J. H., & Berry, A. (2012). Teacher professional development focusing on pedagogical content knowledge. *Educational Researcher*, *41*(1), 26–28. https://doi.org/10.3102/0013189X11431010

Verawati, N. N. S. P., Hikmawati, Prayogi, S., & Bilad, M. R. (2021). Reflective practices in inquiry learning: its effectiveness in training pre-service teachers' critical thinking viewed from cognitive styles. *Jurnal Pendidikan IPA Indonesia*, *10*(4), 505–514. https://doi.org/10.15294/jpii.v10i4.31814

Vitasari, M., Suryani, D. I., Biru, L. T., & Dian, V. (2019). *Implementasi guided inquiry berbasis pedagogical content knowledge (PCK) pada mahasiswa calon guru IPA*. *2*(1).

Voss, T., & Kunter, M. (2020). "Reality shock" of beginning teachers? changes in teacher candidates' emotional exhaustion and constructivist-oriented beliefs. *Journal of Teacher Education*, *71*(3), 292–306. https://doi.org/10.1177/0022487119839700

Vujaklija, A. (2021). Reflective inquiry in teacher education: interanimating authoritative and internally persuasive discourses. *Reflective Practice*, *22*(5), 653–668. https://doi.org/10.1080/14623943.2021.1952972

Wenning, C. J. (2010). The levels of inquiry model of science teaching wenning for explications of real-world applications component of the inquiry spectrum: A levels of inquiry redux. *J. Phys. Tchr. Educ. Online*, *6*(2), 9–16.

Windschitl, M. (2004). Folk theories of "inquiry:" How preservice teachers reproduce the discourse and practices of an atheoretical scientific method. *Journal of Research in Science Teaching*, *41*(5), 481–512. https://doi.org/10.1002/tea.20010

Wolf, R. (2007). Environmental education curriculum resource guide. *December*, 35.

Yanuarti, E., & Treagust, D. F. (2016). Reflective teaching practice (teachers' perspectives in an Indonesia context). *2*, 280–284. https://doi.org/10.2991/icse-15.2016.60