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Chemistry Teachers' Perspectives on the Implementation of Interdisciplinary Science Projects in Vocational Schools: Challenges and Strategic Solutions

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Abstract

The integration of interdisciplinary approaches in science education has gained increasing prominence, particularly within vocational school contexts. The research aims to identify the challenges faced by these teachers and to explore potential solutions for improving project-based instruction within the framework of Indonesia's *Merdeka* Curriculum. This study investigates the perspectives of chemistry education graduates who are currently implementing interdisciplinary science projects (ISP) in vocational schools across Central Java, East Java, and the Special Region of Yogyakarta. Employing a qualitative descriptive design, data were gathered from 25 purposively selected participants using an online open-ended questionnaire. Thematic analysis revealed several core challenges: limited pedagogical competence in project-based learning, difficulties in synthesizing natural and social science content, insufficient laboratory infrastructure and teaching materials, and restrictive curriculum policies that constrain instructional flexibility. These issues were especially pronounced among teachers with mono-disciplinary backgrounds in chemistry, who are now required to deliver integrated and contextualized learning. In response, the participants proposed actionable strategies, including training in contextual and project-based methodologies, mastery of interdisciplinary content, enhanced professional collaboration through *musyawarah guru mata pelajaran (MGMP)* / subject teacher forums, improved access to instructional resources, and flexible curriculum design. The study highlights the need for comprehensive and systemic support to enhance teachers' capacity to deliver meaningful and vocationally relevant interdisciplinary science education. The findings provide critical insights for policymakers, curriculum developers, and teacher education institutions aiming to advance the implementation of holistic STEM education in vocational settings.

Keywords: chemistry teachers, interdisciplinary, science projects, strategic solutions, vocational schools

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1. Introduction

The Indonesian government has taken various steps to improve the quality of education through the implementation of the *Merdeka* Curriculum. The term "*Merdeka*," which translates to "freedom," encapsulates the core philosophy of this curriculum, allowing schools to tailor their educational approaches to better suit the unique characteristics and

needs of their students and communities (Mamuaja et al., 2023; Yunita & Widodo, 2023). Across various educational levels in Indonesia, including vocational schools, this curriculum aims to grant educational institutions the freedom to develop and execute a more relevant and contextual learning process that caters to the needs of students and the requirements of the workforce (Nida et al., 2021; Kasman & Lubis, 2022; Asfiati, 2023; Ferdaus & Novita, 2023; Wardani et al., 2023; Halim et al., 2024). The *Merdeka* Curriculum features a major update with the inclusion of the interdisciplinary science projects (ISP). This project combines elements from both subjects to create a comprehensive unit that enables students to enhance their critical, creative, and collaborative thinking skills by directly engaging with real-world issues.

The main objective of the ISP in the Independent Curriculum is to improve students' understanding of the core principles in the natural sciences and social sciences. This is in line with the goals of the "Independent Curriculum" initiative, which allows schools to develop curricula and teaching approaches that are more relevant to the needs and current developments (Utama et al., 2023). In addition, the project aims to improve the critical and creative thinking skills necessary to analyze complex issues, as well as encourage collaborative teamwork among students. The emphasis on critical thinking is very important in the framework of the independent learning initiatives implemented in the *Merdeka* Curriculum (Kusumawardani et al., 2022). In the context of vocational schools, the implementation of the *Merdeka* Curriculum with the ISP approach aims to prepare students to face the challenges that continue to develop in the world of work and the social environment. This learning approach is designed so that students not only master theoretical material but also develop practical skills that are relevant to industry needs. Therefore, the *Merdeka* Curriculum policy is very important in creating human resources who are competent and ready to compete in the global job market (Hayat et al., 2024).

In the *Merdeka* Curriculum, one of the core topics in the ISP for vocational schools is Matter and Its Changes. This topic reflects essential chemistry concepts such as the classification of matter, distinguishing between elements, compounds, and mixtures, as well as understanding physical and chemical changes. Students are also expected to recognize the characteristics of matter through changes observed in biological, physical, and chemical processes. These competencies provide opportunities to apply chemistry meaningfully through contextual and interdisciplinary projects. For instance, ISP may involve analyzing used lubricants to observe chemical degradation in automotive engineering, extracting natural dyes from local plants for textile and fashion design programs, formulating biodegradable detergents from agricultural waste for industrial chemistry classes, or developing organic pesticide formulations for agricultural technology students (Ferdaus & Novita, 2023).

These projects allow students to explore substance classification, chemical interactions, and transformation processes, while applying chemistry concepts to real-world vocational practices. As such, chemistry education plays a central role in equipping students with scientific thinking in interdisciplinary learning. Recognizing this alignment, many vocational schools assign chemistry education graduates to teach ISP. This positioning offers a unique opportunity for chemistry teachers to contextualize their expertise in broader scientific and social issues, yet also presents challenges in adapting to interdisciplinary demands while preserving conceptual depth and scientific accuracy (Termaat, 2024).

The implementation of the Independent Curriculum, especially in the teaching of the ISP in vocational school, still faces various challenges. One of the main challenges is the limited facilities and infrastructure, such as inadequate laboratories, scarcity of experimental resources, and limited access to modern technology needed to implement project-based learning (Hayat et al., 2024). The dominance of traditional teaching methods that prioritize theory over practical application

is also an obstacle. Many teachers in vocational schools do not have sufficient training in project-based learning techniques, so they find it difficult to implement these methods in their teaching (Sugiyanto et al., 2020).

Although many studies have discussed the implementation of the Independent Curriculum and its challenges, most of them focus more on curriculum policies or assessment of student learning outcomes, while the perspective of teachers as practitioners who implement the curriculum has received less attention. In fact, the teacher's view is very important because they are the closest party to the learning process and can provide deeper insight into the obstacles faced in the field. This research distinguishes itself from previous studies by prioritizing the direct experience of teachers in implementing ISP in vocational schools. Thus, this research focuses on practical aspects, offers solutions that can be directly applied to address the problems faced, as well as providing a space for teachers to share challenges and recommendations that are expected to contribute to the development of a more effective and relevant curriculum in the future (Acosta et al., 2023; Feng & Liang, 2024).

The incorporation of both school-based and work-based pathways is emphasized in the redesign of vocational education, but there remains a lack of flexibility in teaching approaches, especially in project-based learning. Some schools still rely on conventional methods that limit interdisciplinary and practical experiences. To meet the ever-evolving industries and technology, it is essential to implement innovative and flexible teaching methods that support active and contextual learning (Rintala & Nokelainen, 2020). Overcoming these obstacles is vital for the effective implementation of the *Merdeka* Curriculum.

The objective of this research is to investigate the viewpoints of vocational school teachers regarding the instruction of the ISP. Specifically, this study focuses on teachers who hold academic backgrounds in chemistry education and are currently assigned to teach ISP in vocational schools. The study will concentrate on the difficulties they encounter and the remedies they propose based on their professional experience and pedagogical training. By recognizing the primary obstacles and teacher-driven responses, the aim is to offer practical and discipline-informed suggestions for enhancing the quality and effectiveness of project-based learning in vocational education settings (Miller et al., 2021).

Significant improvements in the quality of education in vocational schools can be achieved through the *Merdeka* Curriculum and the ISP approach, but certain challenges must be addressed to achieve these goals. These include limitations in resources, teacher readiness, and curriculum integration. This study is expected to make an important contribution in identifying practical and strategic remedies to address the issues faced by teachers in implementing project-based learning in vocational schools (Pamungkas et al., 2020).

Thus, this article will discuss teachers' views on the implementation of the ISP in vocational schools, identify existing obstacles, and offer applicable remedies to overcome these obstacles. The findings of this study are hoped to serve as a reference for policymakers and education practitioners in improving the quality of learning in vocational schools through the *Merdeka* Curriculum.

2. Research Method

This study investigated the perceptions of 25 teachers in implementing the ISP in vocational schools. This study was a descriptive study with a survey method using a questionnaire technique. The use of this methodology aims to obtain the perceptions directly from teachers who participated in the study (Yuliani, 2018; Ariefin et al., 2022).

Purposive sampling is the sampling technique used in this study. The sample used met the following requirements: (1) have a Bachelor's or Master's degree; (2) currently teaching or

have taught the ISP in the previous academic year; and (3) represent various geographic locations and types of vocational schools. All participants are graduates of chemistry education programs, selected based on their academic background to ensure relevance to the study's focus. Their involvement in ISP, which integrates both natural and social sciences, presents a unique intersection between disciplinary expertise and interdisciplinary teaching demands.

Table 1. Variable Labels & Descriptive Statistics

Variable Label	Percentage	Total Participants
Gender	36% Male 64% Female	25
Age Range	16% 22-28 years 36% 29-34 years 32% 35-42 years 1% 43-50 years 1% 51-59 years	25
Level Education	80% S1 20% S2	25
Teaching Experience	20% 0-5 years 32% 5-10 years 48% 10+ years	25

Questionnaires were distributed electronically (via Google Form) in March 2024 using teacher forums, professional WhatsApp groups, and alumni groups on popular social media platforms commonly used by teachers. The questionnaire contained seven main questions designed to capture three core dimensions: (1) demographic background (including gender, age, education level, teaching experience, school location, and specific vocational subjects taught); (2) perceived challenges and available support in implementing the ISP; and (3) teachers' recommendations and suggestions for improvement. Items 2 and 3 consisted of open-ended questions intended to capture qualitative data.

The following are the demographics of the participants, including age, gender, education level, and teaching experience. From Table 1, we can see the number of females is higher than males: 64% females and 36% males. The majority of participants (44%) were aged 29–34. Then, 32% were aged 35–42. Meanwhile, about 16% were aged 22–28. Only 4% were aged 43–50 and 51–59, respectively. There were no participants aged 60 or above. Most participants held a Bachelor's degree (S1), accounting for 80%. Meanwhile, only 20% held a Master's degree. About 48% had been teaching for more than 10 years, 32% for 5–10 years, and 20% had been teaching for 0–5 years.

Figure 1 illustrates the thematic analysis procedure used in this study. To analyze the responses, a thematic analysis approach was applied. The process involved several steps: initial reading, open coding, theme generation, and interpretation (Rozali, 2022). Particular attention was given to the open-ended responses related to the main obstacles and teacher suggestions in ISP implementation. These responses were inductively coded and grouped into major categories, such as: difficulties integrating interdisciplinary content, limitations in school resources, time constraints, teacher training needs, and curriculum flexibility.

After thematic categorization, the coded responses were quantified by calculating the frequency of each theme mentioned by respondents. These frequencies were then converted into descriptive percentages to show how many teachers highlighted each issue. For example, if 9 out of 25 teachers mentioned "limited content of project skills" as a challenge, this was reported as 36% in the results section. This mixed-mode presentation of qualitative coding and descriptive statistics was used to enhance the clarity and interpretability of findings.

To strengthen data reliability, two assessors independently reviewed and carefully coded the qualitative responses. Inter-coder agreement was established through a thorough and collaborative comparison process, and any discrepancies were resolved through discussion until full consensus was reached. This method enhanced both the consistency and validity of the thematic findings while minimizing potential subjective bias in interpretation.

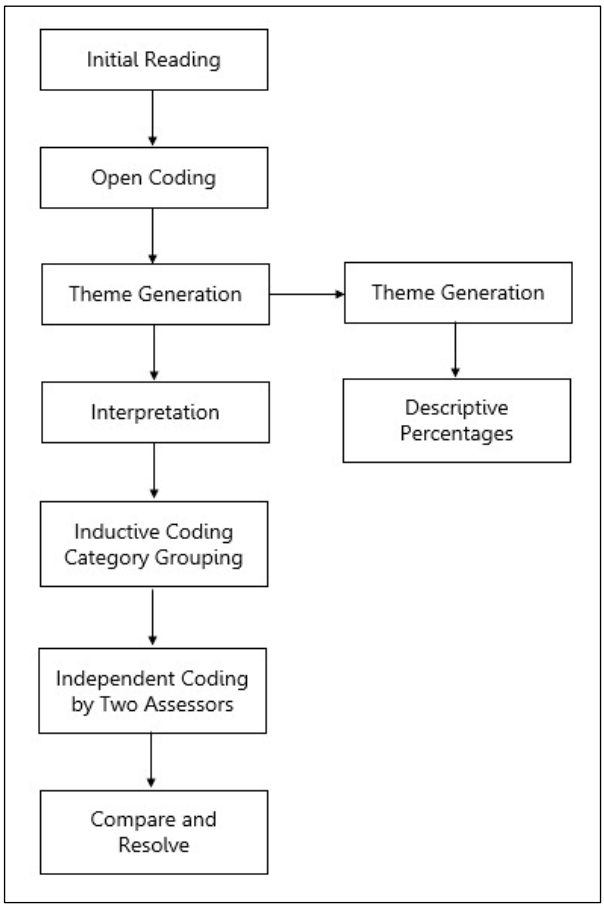

Figure 1. Thematic Analysis Procedure

3. Result and Discussion

The study primarily focused on teachers who currently teach the ISP in several vocational schools located in Central Java, East Java, and Yogyakarta. All participating teachers were graduates of chemistry education programs and were purposefully selected due to their academic background and active teaching roles in the ISP. Their perspectives provide a valuable lens to examine how science-based expertise, particularly from a chemistry discipline, intersects with the interdisciplinary and contextual demands of the *Merdeka* Curriculum.

In line with the decree of *Kepala Badan Standar, Kurikulum, dan Asesmen Pendidikan* Number 032/H/KR/2024, the chemistry component of the ISP includes competencies such as identifying the properties and changes of matter through scientific observation and experimentation. These expectations are embedded in the topic Matter and Its Changes, which directly reflects core chemical concepts. Consequently, the chemistry education background of these teachers is highly relevant for analyzing both their instructional strategies and the specific challenges they face in teaching ISP. Projects such as lubricant analysis, water quality testing, or the formulation of environmentally friendly substances serve as meaningful applications of chemistry within vocational settings and align with national learning standards.

Participants in this study obtained their teaching degrees between 2004 and 2020, with most holding a Bachelor's degree (S1) and a smaller proportion completing a Master's degree (S2). Their teaching experience varied, ranging from under five years to over a decade, offering a wide spectrum of insights across generations of vocational education practitioners. Respondents were drawn from diverse districts, including Pati, Semarang, Banyumas, Brebes, Sidoarjo, Lamongan, and Kulon Progo. This geographic and experiential diversity enhances the representativeness of the findings and supports a well-rounded understanding of the contextual factors influencing ISP implementation.

To explore their perspectives, a structured questionnaire was administered electronically. It comprised seven open-ended items targeting three main areas: demographic information, challenges and supports in implementing ISP, and teachers' recommendations for improvement. The initial items asked teachers to describe both general and specific obstacles they encountered, especially those arising from the integration of natural and social sciences as well as the shift toward project-based learning. Follow-up items addressed school infrastructure, resource availability, and collegial support. The final items invited reflection on factors of successful instruction and solicited suggestions for strengthening teacher readiness, particularly through training and professional collaboration.

Thematic analysis of the responses, supported by descriptive quantification, revealed that the primary difficulties encountered by chemistry-trained teachers included mastering interdisciplinary content, applying project-based pedagogy effectively, and managing with limited school resources. These findings reflect the complex and evolving nature of instructional practice under the ISP. Despite such challenges, many respondents demonstrated adaptive teaching behaviors, such as collaborating with peers across disciplines, utilizing accessible local materials, and independently seeking pedagogical innovation. Although the sample size is relatively small, the study contributes meaningful insights into the practical implementation of chemistry-based interdisciplinary instruction in vocational schools, and highlights strategic areas for policy support and professional development.

3.1. Teachers' Perspectives on ISP Teaching Obstacles

According to the assessment, the primary difficulty recognized by the majority of ISP teachers is integrating project-based learning with the established learning objectives. This is depicted in Figure 2, which indicates the percentage of barriers encountered by the teachers.

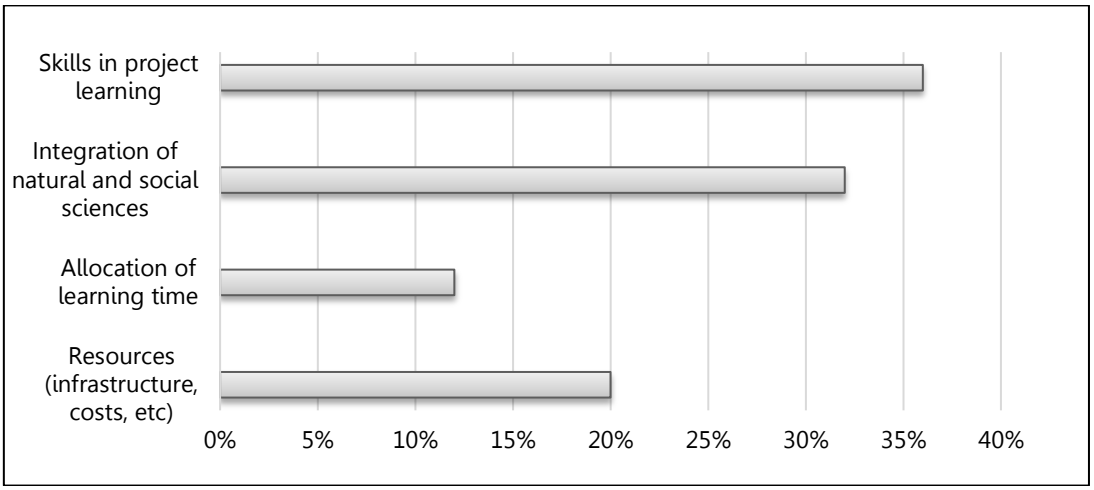

Figure 2. Percentage of Teacher Obstacles in Teaching ISPs

The ideal alignment of the ISP in vocational schools should be with the students' vocational skills. Enhancing competence and preparing students for real-world obstacles can be achieved by integrating ISP learning with vocational skills. Vocational education has recognized project-based learning as an effective approach to motivate students from diverse backgrounds, improve problem-solving skills, and enhance critical thinking abilities (Jalinus et al., 2019; Pamungkas et al., 2020; Miller et al., 2021).

In vocational education institutions, it is highly advised to incorporate project-based learning (PBL) in order to enhance students' skills and enrich their educational journey. This educational approach aligns with the core principles of vocational education, placing a strong emphasis on empowering students as central participants in the learning process. As a result, it helps students develop important emotional and psychomotor skills (Jalinus et al., 2019). PBL allows students to independently utilize knowledge acquired from real-life projects, which is crucial for attaining the 21st-century skills necessary for career success (Le et al., 2022; Pamungkas et al., 2020; Syahril et al., 2022).

However, the responses from participants in this study, all of whom are chemistry education graduates currently assigned to teach ISP in vocational schools, reveal several key barriers in the implementation process. These challenges extend beyond general difficulties in executing project-based learning and are closely related to the epistemological

shift that teachers must navigate. As shown in Figure 2, approximately 36% of respondents reported limited proficiency in managing project learning, while 32% indicated difficulties in integrating content from both natural and social sciences. These findings are particularly significant given that most of the teachers involved were academically trained within a single-discipline framework rooted in chemistry, yet are now expected to design and facilitate interdisciplinary learning experiences.

Teachers encounter a major challenge in integrating natural and social sciences, which poses pedagogical barriers due to the need for a multidisciplinary approach that recognizes the influence of socialization experiences, relationships, and context on the development of critical awareness. Implementing this type of learning is difficult for teachers with expertise in only one scientific field. Combining different fields into a cohesive learning experience for students demands teachers' ability to adapt and deeply understand the content of the ISP (Masava et al., 2023; Kreijkes & Greatorex, 2024). This challenge is consistent with interdisciplinary education research, which highlights the complexity of curriculum integration (Bullard et al., 2019).

This issue becomes even more evident when considering the specific chemistry-related content embedded in ISP, particularly the topic *Matter and Its Changes* as outlined in the official learning outcomes document of the curriculum. Teachers are expected to guide students through projects involving the classification of matter, physical and chemical changes, or the behavior of mixtures—content strongly rooted in fundamental chemistry principles. Yet, as reported in the qualitative responses, many teachers struggle to design context-based projects that meaningfully connect such scientific content with broader, real-world social or vocational issues relevant to students' future careers.

The ISP's interdisciplinary methods may not have an impact on teachers' professional identity because they involve a limited number of subjects (Termaat, 2024). However, teachers could face difficulties in meeting curriculum requirements and effectively applying pedagogical methods if they lack proper training (Acosta et al., 2023). It is crucial to have a program approach that encompasses all disciplines in integrating the curriculum (Armbruster et al., 2022). Without comprehensive support and structured professional development, teachers may struggle to balance the interdisciplinary demands of ISP with the need to maintain subject-specific depth. Furthermore, the absence of collaborative planning opportunities among teachers from different disciplines can lead to fragmented instruction and limit the coherence of project implementation. Therefore, a well-designed, cross-disciplinary teacher support system is essential to ensure the effective realization of ISP's objectives.

In addition to internal challenges related to interdisciplinary integration, the findings also highlight external barriers that hinder the effective implementation of ISPs in vocational schools. Among the surveyed teachers, 20% cited the lack of infrastructure and teaching resources as a key constraint (see Figure 2). This reflects a broader issue in science education, where limited laboratory equipment, consumables, and access to digital tools often undermine teachers' ability to deliver meaningful, hands-on learning. For chemistry-trained teachers in particular, the absence of standard scientific apparatus restricts their capacity to design and guide projects aligned with core chemical competencies, such as solution preparation, titration, and separation techniques. Insufficient equipment and facilities pose serious challenges when carrying out industry-relevant and demanding projects (Cintang et al., 2018). The effectiveness of project-based learning is further limited as both educators and students require the necessary knowledge, skills, and access to appropriate tools for successful implementation (Uyen et al., 2023).

Furthermore, time allocation emerged as another significant challenge, with 12 percent

of teachers reporting difficulty in adjusting project activities within the existing curricular schedule. Considering the demanding nature of project-based learning, which requires extended periods for planning, experimentation, and student collaboration, rigid timetable structures often diminish instructional flexibility. Teachers are required to manage these time constraints while simultaneously ensuring that students achieve interdisciplinary learning outcomes as well as a solid understanding of fundamental concepts related to matter and its changes, which represent a key competency in the chemistry component of the ISP. This combination of infrastructural and temporal limitations complicates the translation of project-based learning into authentic vocational contexts. In the absence of adequate support systems, including functional laboratories, curriculum adapted project modules, and access to tools that are relevant to industry practices, teachers encounter difficulties in implementing projects that are both pedagogically rigorous and practically applicable.

Incorporating industry experts into research collaborations can provide teachers with valuable practical experience in applying theoretical knowledge to real-world issues (Feng & Liang, 2024). Teachers encounter various obstacles when implementing project-based teaching approaches, such as overseeing the educational process, working within resource constraints, handling student readiness, and managing time limitations (Tain et al., 2023). In schools, teachers' lack of technological proficiency, time constraints in the curriculum, inadequate professional development opportunities, and a shortage of technical support and resources can all impede the incorporation of Information and Communication Technology (ICT) in education (Baya'a et al., 2019).

Altogether, these findings emphasize that teaching ISPs requires a holistic instructional ecosystem. This ecosystem should integrate interdisciplinary pedagogies, ensure adequate allocation of time and learning resources, and promote innovation among teachers who possess disciplinary backgrounds primarily in chemistry education. Addressing these systemic challenges is essential not only to improve the quality of ISP implementation but also to enable chemistry education graduates to contribute meaningfully to the objectives of vocational science education.

3.2. Teachers' Perspectives on ISP Teaching Remedies

Based on a thematic analysis of open-ended responses from participating teachers, five major categories of suggested remedies emerged in direct response to the challenges they encountered during the implementation of the ISP. As all participants in this study were graduates of chemistry education programs currently teaching ISP in vocational schools, their recommendations reflect not only general pedagogical concerns but also specific strategies rooted in their mono-disciplinary training backgrounds. These categories include: (1) contextual and project-based training, (2) interdisciplinary content mastery, (3) collaborative learning communities (e.g., *MGMP*), (4) improved laboratory and resource support, and (5) curriculum flexibility. Each theme was inductively derived from the narratives provided by the teachers and reflects a grounded understanding of the instructional barriers within vocational school contexts.

To enhance interpretability, the frequency of each thematic category was quantified. As shown in Figure 2, training and professional development were most frequently mentioned, accounting for 36% of the responses. This was followed by the need for interdisciplinary mastery (24%), the strengthening of collaborative teacher networks (16%), and improvements in both school resources and curriculum flexibility (12% each). It is important to note that these percentages are based on a multiple-response analysis, where individual participants often cited more than one suggestion. This approach captures the nuanced and multifaceted nature of the support teachers need.

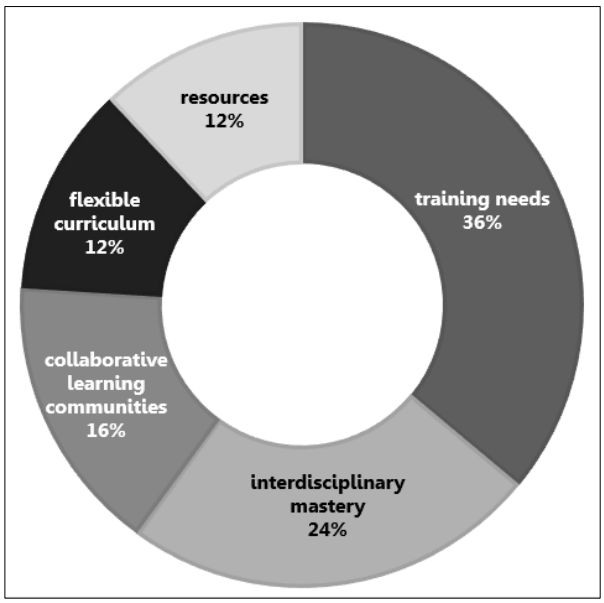

Figure 2. Distribution of Teacher-Suggested Remedies for Overcoming ISP Implementation Challenges

The most common solution written by teachers is training and professional development that leads to project and contextual learning. This recommendation was expressed by 36% of the respondents, making it the most frequently cited remedy. Teachers require interactive, collaborative instruction to explore teaching methods like task-based learning and gain insights from experts. Creating valuable and relevant learning opportunities can be challenging, yet it is crucial for enhancing teaching practices. In addition, professional development programs should be continuous and supported institutionally to ensure long-term impact. These trainings should also be tailored to the specific context of vocational education, integrating real-world industrial practices and interdisciplinary approaches to better equip teachers in delivering ISP.

Training programs need to emphasize offering support in creating lesson plans, utilizing strategies, and incorporating technology to guarantee the successful execution of lesson plans (Hidayat et al., 2024). These initiatives should be designed to address specific challenges in implementing interdisciplinary projects and to align with vocational education contexts. As noted by respondents, contextual-based training can bridge the gap between teacher knowledge and curriculum expectations, ensuring more effective teaching practices (Acosta et al., 2022). In line with the situated learning theory (Green et al., 2018), such training also prepares teachers for the realities of classroom instruction.

Teachers with existing expertise gained from training are anticipated to bring creativity to the instructional environment. Enabling teachers with training initiatives emphasizing collaborative skills can lead to educational advancement and enhance student performance (Kratumnok & Phrakhrusutheejariyawattana, 2024). Genuine learning opportunities not only strengthen pedagogical skills but also cultivate a reflective mindset to evaluate and refine teaching strategies (Walimbwa et al., 2022). Furthermore, such training can empower teachers to better adapt to curriculum demands, manage interdisciplinary content, and design engaging, context-based projects that align with both academic standards and industry relevance. Continuous support and feedback mechanisms are also essential to ensure that professional development translates effectively into classroom practice.

The intricate nature of the ISP, which integrates both natural and social sciences, presents unique difficulties for teachers who usually specialize in only one of these disciplines. To address this, 24% of the teachers emphasized the need for interdisciplinary content mastery. This finding highlights the urgent demand for professional development that goes beyond disciplinary limitation and equips teachers with integrative thinking skills. Teachers must not only understand core concepts from multiple disciplines but also learn how to synthesize them into meaningful, student-centered learning experiences. Without sufficient interdisciplinary training, teachers may struggle to guide students through projects that require analysis from diverse scientific and social perspectives.

In line with this need for interdisciplinary mastery, some respondents shared examples

of ISPs they had designed that directly incorporate chemistry content into vocational contexts. Several ISPs designed by chemistry education graduates demonstrate how the topic matter and its changes can be applied meaningfully across diverse vocational contexts. In the fashion and textile programs, students designed an ecoprint project by extracting natural pigments from leaves, flowers, or bark and transferring them onto fabric using heat and pressure. This process involved both physical and chemical changes—such as pigment solubilization, oxidation, and fixation of dye molecules onto textile fibers—illustrating real applications of solubility and chemical bonding. In agricultural schools, students developed organic pesticides from fermented plant extracts like neem, papaya leaves, or chili. During the fermentation process, they observed indicators of chemical change including color shifts, odor formation, and the production of active compounds such as alkaloids and flavonoids that act as biopesticides.

In automotive programs, students explored rust prevention by comparing metal corrosion in various conditions (e.g., exposed to water, acid rain simulants, or coated with oil). This project allowed students to investigate chemical changes such as oxidation and the role of inhibitors. In culinary or food processing vocational tracks, students designed a project on food preservation, testing how acidity, salt, or temperature affect spoilage rates. These activities helped them understand the interaction of substances, reversible and irreversible changes, and the role of pH in microbial activity. These examples reveal how chemistry teachers, though trained in a mono-disciplinary framework, were able to guide students through interdisciplinary, context-rich explorations. The projects were intentionally designed to be simple, safe, and relevant, allowing students to engage with core chemical concepts such as physical and chemical changes, separation of mixtures, pH, and the transformation of matter—while strengthening their vocational competencies in a meaningful way.

These interdisciplinary projects enabled students to explore core chemistry concepts such as physical and chemical changes, solution behavior, and compound interactions within practical vocational contexts. By applying science to real-life tasks, students gained deeper understanding of how chemical principles operate in their field of study. At the same time, chemistry teachers demonstrated adaptability by bridging their disciplinary expertise with interdisciplinary demands. This approach aligns with the goals of the ISP to foster contextualized scientific literacy in vocational education.

Creating valuable and practical learning experiences requires comprehensive training across multiple areas rather than just focusing on one subject. Teachers should broaden their expertise to cover a range of disciplines instead of solely focusing on one subject. Engaging in interdisciplinary training programs can improve teachers' skills and knowledge, ultimately resulting in higher teaching quality and better student learning outcomes. According to (Santaolalla et al., 2020), an interdisciplinary approach allows teachers to connect various concepts across different subjects, making learning more relevant and contextual for students. This significance is crucial for capturing students' interest and illustrating the real-world relevance of their learning.

A smaller, yet meaningful, proportion of respondents (16%) stressed the importance of collaborative learning communities such as *MGMP* (Teacher Forum on Subject Matter). These forums provide a space for teachers to share practices, develop shared understandings, and access peer support (Admiraal et al., 2021). Such communities are particularly important in contexts where teachers face interdisciplinary teaching without adequate institutional support. By working together, teachers not only gain resources and ideas, but also emotional and professional reinforcement in managing curriculum changes.

Being involved in the Teacher Forum on Subject Matter (MGMP) is essential for

teachers to enhance Teachers in these regions have the opportunity to obtain additional materials, acquire new concepts, and receive valuable input to improve their teaching approaches through working together. Collaborating in these collectives also encourages the creation of creative teaching methods and the ability to solve problems, ultimately raising the quality of education in vocational institutions. Their knowledge and skills in implementing teaching methods. Teachers can benefit from additional resources, new ideas, and useful input, all of which help improve their teaching techniques. Having this community in place also helps teachers feel more encouraged and supported in their quest for continuous learning and growth. Consequently, collaborative and multidisciplinary learning communities offer benefits not only to teachers but also to students, who will receive a superior quality of education.

Additionally, 12% of the teachers suggested improving learning facilities such as laboratories and experimental materials. These are critical for supporting hands-on, inquiry-based approaches that bring ISP learning to life. The ability to design compelling and relevant experiments is highly dependent on resource availability, and many teachers emphasized the need for schools to provide adequate infrastructure to support such innovative practices (Santosa & Sukmawati, 2024). Teachers are able to create and carry out experiments that enhance students' comprehension and curiosity in learning due to having well-equipped labs and enough experimental materials. It's important for schools to regularly update these facilities to align with the latest scientific and technological developments, allowing theory to be connected with practical applications effectively.

The final 12% of suggestions focused on the importance of curriculum flexibility. Teachers acknowledged that rigid scheduling and curricular structures often hinder the effective implementation of project-based learning. Allowing for more adaptable timetables and teaching autonomy enables educators to meet students' diverse needs, engage in deeper learning experiences, and promote 21st-century skills such as critical thinking, collaboration, and problem-solving. Empowering teachers to make instructional decisions enhances their motivation and sense of ownership, which ultimately contributes to better student outcomes.

Improving the learning process can be more effective when teachers have the flexibility to adapt the curriculum. By allowing teachers to tailor their teaching methods to fit the unique needs and interests of their students, a flexible curriculum makes it possible for them to spend more time on projects that involve thorough research and collaboration. This approach helps students gain a deeper understanding of the material. Additionally, such flexibility enables educators to integrate real-world contexts into classroom activities, making learning more relevant and engaging. When teachers are empowered to adjust pacing and content, they can better support diverse learning styles and address gaps in student comprehension.

To synthesize the findings of this study, a visual mapping of the relationship between thematic challenge categories, their specific manifestations, and the corresponding teacher-proposed solutions is presented in Figure 3. This integrative framework highlights how the obstacles encountered in implementing the ISP—such as curriculum misalignment, interdisciplinary complexity, infrastructural limitations, and time constraints—are met with practical, context-driven strategies rooted in teacher experience. These include the demand for contextual and project-based training, interdisciplinary content mastery, improved resource provision, collaborative support structures, and curriculum flexibility. The alignment between challenges and suggested solutions, as illustrated, reinforces the need for targeted interventions that are both pedagogically sound and responsive to real classroom conditions.

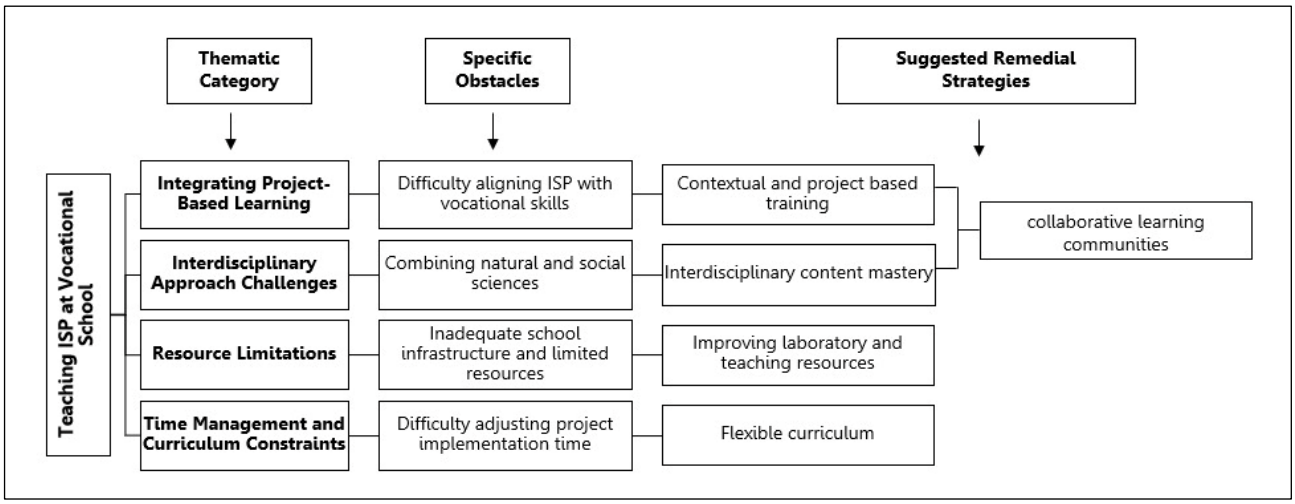

Figure 3. Mapping of Obstacles and Remedies for Teaching ISP

These findings underscore the importance of listening to teachers' voices in shaping effective educational policy and practice. As the direct implementers of the curriculum, teachers possess valuable experiential knowledge that often goes unrecognized in top-down reform initiatives. By incorporating their feedback into decision-making processes, educational stakeholders can develop more realistic, context-sensitive strategies for improving interdisciplinary and project-based learning. This participatory approach not only increases the likelihood of successful implementation but also fosters a sense of ownership and motivation among educators, which is crucial for sustainable and impactful change.

In conclusion, the challenges faced by teachers in implementing the ISP are met with grounded and pragmatic solutions that reflect their professional insight and lived experiences. These include the need for continuous professional development, interdisciplinary training, collaborative forums, improved learning infrastructure, and greater curriculum flexibility. When these teacher-driven recommendations are aligned with systemic educational reforms, they have the potential to enhance instructional quality, empower educators, and better prepare vocational students for the complex demands of future careers, while honoring the essential role of teachers as agents of change in education.

4. Conclusion

Teachers involved in the implementation of the ISP at vocational schools in Central Java, East Java, and Yogyakarta, most of whom are graduates of chemistry education programs, face a variety of intricate challenges in translating interdisciplinary, project-based learning into meaningful classroom experiences. Among the most prominent difficulties are the integration of natural and social science content into cohesive instructional designs, the adaptation of project-based methodologies within limited instructional time, and the lack of adequate laboratory infrastructure and learning materials. These challenges are further compounded by rigid curriculum structures that restrict pedagogical flexibility and innovation.

Despite these constraints, participating teachers demonstrate remarkable pedagogical agency and adaptability. Many of them respond to these demands by designing simpler, contextually grounded projects; extending their pedagogical repertoire beyond chemistry to accommodate interdisciplinary content; and utilizing locally available resources to support authentic learning. Their efforts exemplify a reflective and solution-oriented approach to educational reform, especially within the rapidly evolving landscape of vocational education.

In conclusion, the obstacles encountered in ISP implementation are countered by practical, experience-driven strategies that emerge from the teachers' direct engagement with the curriculum. These include calls for sustained professional development, interdisciplinary capacity building, peer collaboration through teacher forums such as MGMP, enhancement of learning facilities, and increased curriculum flexibility. When these teacher-informed strategies are synergized with systemic support, they not only strengthen the quality of instruction and empower educators, but also prepare vocational students to meet the demands of an increasingly complex and interdisciplinary world. Ultimately, this study affirms the pivotal role of chemistry education graduates as key agents in bridging scientific knowledge with real-world vocational contexts through the ISP framework.

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