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The Principal's Leadership in Integrating Deep Learning, Coding, and Artificial Intelligence in Elementary Schools

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ABSTRACT
This research aims to analyze how the principal integrates Deep Learning, Coding, and Artificial Intelligence (DL–CAI) at SD Negeri 011 Balikpapan Tengah. This research uses a qualitative method with a case study design. Data were obtained through semi-structured interviews with four purposively selected informants, namely the school principal, teachers who are members of the Curriculum Development Team, technology ambassadors, and implementing class teachers. Data analysis follows the interactive model of Miles and Huberman with the help of QualCoder version 4.0 software, through manual coding, review and grouping of codes, theme formation, and conclusion drawing and verification. The validity of the data was tested through source triangulation. The analysis results in 18 codes, four subthemes, and two main themes, namely the strategic and collaborative leadership of the principal and the gradual and adaptive management of the PM-KKA integration. The principal leads the implementation of the program through planning, role distribution, teacher empowerment, peer mentoring, and academic supervision. However, there are still challenges such as the gap in teacher competencies, limited infrastructure, and differing understandings in the use of technology. This research presents a conceptual synthesis on collaborative, adaptive, and pedagogically oriented school leadership. These findings expand the understanding of the relationship between instructional leadership and digital leadership in managing learning changes in elementary schools.

1. INTRODUCTION

The development of technology is changing the way students obtain information and learn, so schools need to adjust their teaching methods so that students can think critically, solve problems, and apply the knowledge they have gained. Syaputra & Hasanah (2022) emphasize the need for strategy adjustments and the enhancement of teacher competencies in the digital era. The results of PISA 2022 show that Indonesian students' achievements in reading, mathematics, and science are still below the OECD average (OECD, 2023). Although PISA assesses 15-year-old students and does not directly measure learning in elementary schools, the results underscore the importance of strengthening thinking skills from early education. Education policies in Indonesia encourage the implementation of Deep Learning and the introduction of Coding and Artificial Intelligence (PM–KKA). Deep Learning emphasizes a conscious and meaningful learning process, while Coding and Artificial Intelligence are elective subjects whose implementation is adjusted according to school resources (Ministry of Primary and Secondary Education, 2025). The PM–KKA model school guide for 2026 includes planning, implementation, monitoring, and program evaluation (Anggraena et al., 2026). The implementation of this program requires teacher readiness, facility support, and school management to ensure that learning meets students' needs. The implementation of PM–KKA needs to consider the role of each component in the learning process. Afrikasari, Hasanah, & Hidayati (2025) found obstacles in the planning and development

of deep learning in elementary schools. Rina & Hasanah (2024) highlighted the importance of student readiness and resource management in schools. Fagerlund, Häkkinen, Vesisenaho, & Viiri (2021) discuss the use of Scratch to develop computational thinking skills, while Dağ, Şumuer, & Durdu (2023) and Afifah, Ulfa, Setyosari, & Soepriyanto (2025) show that these skills can also be developed through coding without digital devices. These findings emphasize the importance of considering learning objectives, student abilities, and school conditions in the implementation of education. The use of artificial intelligence provides opportunities for teachers to develop learning materials and activities, but its use needs to be considered carefully. Rachmadtullah et al (2024) examined teachers' experiences in utilizing AI as a learning medium. Chiu, Xia, Zhou, Chai, & Cheng (2023) discuss the opportunities and challenges of using AI in education, while Tan, Cheng, & Ling (2025) highlight the importance of developing teacher competencies. Information from AI must be verified to ensure the material is accurate, meets students' needs, and keeps data secure. Therefore, the use of AI requires pedagogical understanding and school support, not just technical skills. School readiness becomes a challenge in implementing technology-based learning programs. Ambarwulan (2025) found that teachers' knowledge of coding and artificial intelligence is not always accompanied by the readiness to implement it. Prihatin (2025) emphasizes the importance of curriculum readiness, digital infrastructure, and learning strategies. Sulistyo & Tanesab (2026) show that the implementation of the Coding and Artificial Intelligence policy varies in each school due to differences in support, teaching materials, and teacher guidance. Schools need to determine the implementation steps according to the resources they have, not just follow administrative regulations.

The principal is responsible for setting priorities, managing resources, and supporting the professional development of teachers. Santosa (2022) and Wibowo & Santosa (2022) emphasize that the development of teacher professionalism is related to the principal's strategies through planning, supervision, collaboration, and mentoring. Ansori, Suyatno, & Sulisworo (2021) demonstrate the role of the principal in enhancing teachers' pedagogical and professional competencies. Instructional leadership places the quality of learning as the main focus (Abdurrahman & Hasanah, 2026), while digital leadership relates to the principal's ability to manage change and support the use of technology (Hasanah & Mohd Yusoff, 2024). Both approaches are necessary for school principals to maintain learning objectives and help teachers adapt to technological advancements. The implementation of a new program in schools is not enough just by making policies and dividing tasks. Fixsen, Ward, & Blase (2025) emphasize that the successful implementation of educational programs requires planned capacity development and organizational support. Sulistyowati, Santosa, & Hasanah (2026) show that the readiness of school principals in Deep Learning is related to conceptual understanding, support for teacher innovation, learning environment, and the use of technology. These findings underscore the importance of leadership in preparing for program implementation, as well as the need to assess school readiness and support through the relationship between principal decisions, teacher experience, and follow-up during the program. Previous studies on instructional leadership, digital leadership, teacher readiness, and the implementation of PM–KKA provide a foundation for understanding changes in learning in elementary schools. However, the management of these three learning components through the principal's leadership strategy in the context of model schools still requires further study. SD Negeri 011 Balikpapan Tengah was chosen as the research location because it is one of the PM–KKA model schools in Balikpapan City in 2026. This study aims to understand the principal's strategies in program planning and coordination, teacher empowerment, obstacle handling, and the evaluation of PM–KKA implementation. The main focus of the research is on the relationship between the principal's decisions and changes in learning at the educational unit level.

2. METHODS

A qualitative approach was chosen to gain an in-depth understanding of the principal's leadership in the implementation of PM–KKA at SD Negeri 011 Balikpapan Tengah. Understanding of the research phenomenon is built based on the experiences and statements of the parties directly involved (Rusandi & Muhammad Rusli, 2021). The case study design was chosen because the research focuses on one school, taking into account the conditions and processes of program implementation (Assyakurrohim, Ikhram, Sirodj, & Afgani, 2022). The research examines program planning, task distribution, teacher mentoring, and obstacles to the implementation of PM–KKA by the school principal. The selection of informants used purposive sampling techniques, considering their involvement, knowledge, and experience in the implementation of PM–KKA (Lenaini, 2021). The research involved four informants: the school principal (SP), teachers who are members of the Curriculum Development Team (CDT), technology ambassadors (TA), and classroom teachers (CT). The school principal provided information about program policies and management, the CDT teachers related to curriculum adjustments, the technology ambassadors regarding support for technology use, and the classroom teachers about the implementation of PM–KKA and learning obstacles. The four informants were selected because they have different responsibilities and experiences in the implementation of the program. The codes and roles of the informants are presented in Table 1.

Table 1. Codes and roles of research informants

Code	**Informant**	Number of Questions
KS	Principal	15
TPK	Teacher member of the Curriculum Development Team	15
DT	Technology ambassador	15
GP	One teacher for the PM–KKA implementation class	15

Note: Each informant used an interview guide consisting of 15 questions, with adjustments based on their respective roles.

Data collection was conducted through semi-structured interviews with guidelines tailored to the research focus. Each informant received 15 questions tailored to their role. The questions include program planning, leadership strategies, task distribution, teacher mentoring, lesson implementation, obstacles, and PM–KKA evaluation. The interview was conducted on November 6, 2026, and recorded in audio format for transcript preparation. The interview with the technology ambassador was conducted via Zoom because the informant was attending training in Jakarta. The recording is used as the basis for transcription and data analysis. Data analysis in this study refers to the interactive model of Miles and Huberman, which includes data collection, data reduction, data presentation, and conclusion drawing and verification (Qomaruddin & Sa'diyah, 2024). Interview data is reviewed to select information related to the research focus, then grouped based on similarities in content and issues found. The results of the categorization are presented in the form of categories and themes to facilitate the researcher in seeing the relationships between the interview results. Conclusions are drawn by comparing the statements from the four informants and rechecking their consistency with the available data. The validity of the data was examined through source triangulation by comparing information from the school principal, teachers who are members of the Curriculum Development Team, technology ambassadors, and teachers implementing the PM–KKA. The comparison was conducted to identify similarities and differences in statements regarding leadership strategies, program implementation, and the obstacles faced. The information obtained was also reexamined based on the interview transcripts

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to ensure the consistency between the data and the analysis results. Because the research in this article uses interview data, the research results are limited to the information and experiences conveyed by the informants. The stages of data analysis using the interactive model of Miles and Huberman are presented in Figure 1. The feedback arrows indicate that the analysis process allows for a re-examination of the data that has been collected. For example, when discrepancies in testimonies among informants are found, researchers can revisit the codes and interview transcripts before drawing conclusions.

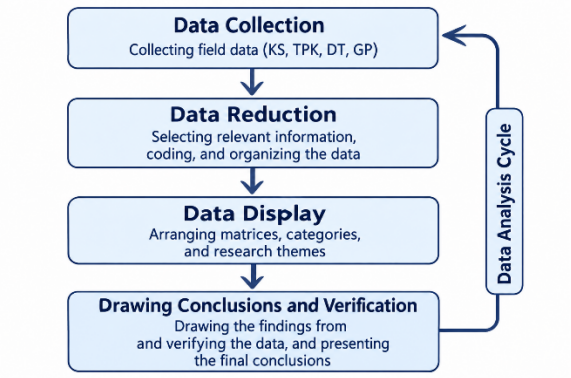


Figure 1. Research Data Analysis Flow

3. RESULTS AND DISCUSSION

RESULTS

The results of the interview data analysis with four informants using the QualCoder software produced 18 codes grouped into four subthemes and two main themes, namely (1) the strategic and collaborative leadership of the principal and (2) the gradual and adaptive management of PM-KKA integration. Both themes show the interconnection between the principal's leadership strategies, the development of teachers' competencies, and the adjustment of learning implementation to the school's conditions. Although there is alignment in the direction of learning, the level of implementation of Deep Learning, Coding, and Artificial Intelligence is not yet uniform due to differences in teacher readiness and limited school resources.

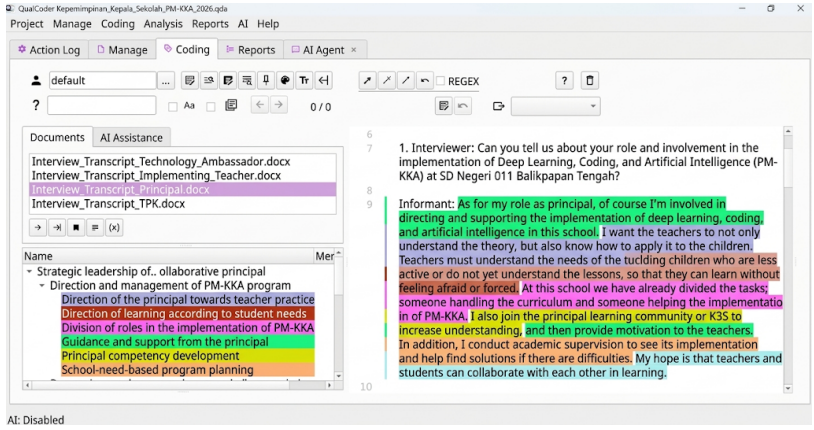


Figure 2. The Process of Coding Interview Data Using QualCoder

The coding categorization was carried out by considering the similarity of meanings, the interrelation between codes, and their relevance to the research focus. The first theme describes the principal's strategies in directing programs, organizing human resources, and supporting the development of teachers' competencies. The second theme illustrates how this leadership direction relates to the implementation of PM–KKA integration, tailored to the needs of students, teacher readiness, and school conditions. The relationship between codes, sub-themes, and main themes is presented in Figure 3.

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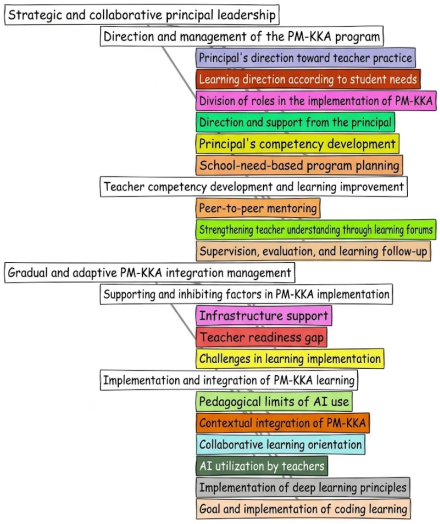


Figure 3. The Process of Formulating Research Themes

The relationship between the two themes shows that the principal's leadership in integrating PM–KKA has collaborative, adaptive, and pedagogical-oriented characteristics. The principal directs the implementation of the program through planning, role distribution, teacher competency development, and academic supervision. In its implementation, Deep Learning serves as the pedagogical foundation, coding is directed toward developing computational thinking skills, while artificial intelligence is utilized as a teaching aid and for introducing technology to students. However, the gap in teacher competence and limited infrastructure indicate that the integration of these three components still requires continuous support, evaluation, and follow-up. The conceptual relationship between these findings is presented in Figure 4.

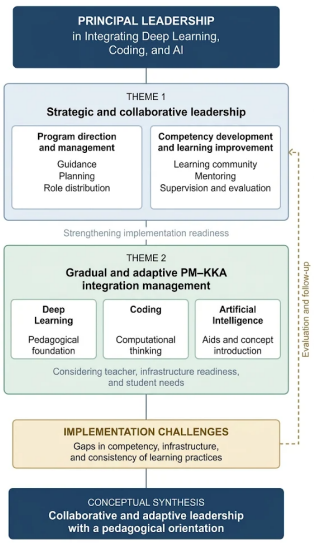


Figure 4. Conceptual Framework of School Principal Leadership in Integrating PM–KKA

3.1 Strategic and Collaborative Leadership of the Principal

The strategic and collaborative leadership of the principal is reflected in program management, teacher empowerment, and efforts to improve learning. In the implementation of PM–KKA, the principal not only provides direction but also involves teachers according to their respective competencies and responsibilities. Direction and Management of the PM–KKA Program

The principal directs the program planning by considering the needs of the students and the conditions of the school. Planning is not only oriented toward organizing activities but also on how teachers understand and apply the principles of meaningful learning. This was conveyed by the principal as follows: "So, from the planning stage, we need to think about how the material can truly be understood and felt beneficial by the children." (Principal, Interview 3) In addition to directing program planning, the principal organizes human resources through the division of roles and responsibilities. This statement is supported by the Technology Ambassador. "For the division of roles, the principal has formed several teams established through a decree." (TA, Interview 5) The division of roles does not limit coordination to formal mechanisms. A teacher member of the Curriculum Development Team explained that coordination also takes place through discussions among teachers. "In practice, we prioritize collaboration among teachers. Coordination does not always take the form of official meetings." (TPK, Interview 5). The findings show that the management of the PM–KKA program combines formal organization by the principal with informal collaboration among teachers. The principal plays a role in setting the direction and distributing responsibilities, while teachers have the space to adjust teaching strategies to meet the needs of the class. Thus, the principal's leadership is not only reflected in administrative functions but also in empowering teachers to translate program directions into learning practices.

Development of Teacher Competence and Improvement of Learning In facing the differences in teacher readiness, the principal develops mentoring strategies through learning communities, Teacher Working Groups (KKG), and technical guidance. The principal also empowers teachers with more competence and experience to mentor their peers. The learning community, which according to the principal is held at least once a week, becomes a space for teachers to discuss challenges and share learning experiences. The importance of peer mentoring was expressed by the implementing teacher. "I myself, even though I have already attended the training, still consult with fellow teachers who understand better." (GP, Interview 6). The statement indicates that formal training has not fully met the needs for teacher competency development. Peer mentoring becomes a professional learning mechanism that complements training. In addition to empowering teachers, the principal also strives to improve learning through academic supervision. "In supervision, I emphasize that the goal is not to find faults, but to help teachers find solutions to improve learning." (KS, Interview 6) In line with this statement, the Technology Ambassador explained that evaluation is conducted through academic supervision, collaborative inquiry activities, learning documentation, and reflection. However, when asked about evidence supporting the assessment of the strategies implemented, the principal expressed limitations. "For specific assessments, there isn't much I can share at the moment." (KS, Interview 14) These findings indicate that the principal's leadership in developing teacher competencies emphasizes empowerment, collaboration, and supervision focused on improving learning. Although the mentoring and evaluation mechanisms have been reported to be in place, evidence regarding the effectiveness of these strategies in supporting the integration of PM–KKA is still limited.

3.2 Gradual and Adaptive Management of PM–KKA Integration

The management of PM–KKA integration shows an adjustment between the direction of the principal's leadership and the needs of students, teacher readiness, and school conditions. These three components are implemented with varying levels of depth, but they are directed toward interrelated pedagogical goals. Implementation and Integration of PM–KKA Learning The principal provides teachers with the flexibility to adjust teaching strategies to meet students' needs without requiring the use of technology in every learning activity. "Coding and AI have also started to be implemented in schools, but that doesn't mean all learning has to use AI. Teachers can adjust their teaching methods to the needs of the children." (KS, Interview 10) This direction is reflected

in the teachers' experiences in applying contextual learning, such as the counting shop activity in the fourth grade. Meanwhile, coding education is still at the stage of introducing computational thinking skills through an unplugged approach. The interconnection of these three components was explained by the Technology Ambassador. "So, deep learning becomes the main approach, while coding and artificial intelligence are linked to contextual learning experiences." (TA, Interview 10) Despite the alignment in pedagogical orientation, differences were found in the informants' statements regarding the use of AI by students. "Children can use it, but they must still be under the supervision of a teacher." (TPK, Interview 9) Meanwhile, the Technology Ambassador stated: "We have not yet given students direct access to use AI." (TA, Interview 9). The differences indicate a possible gap between the understanding of permitted AI usage and its practical application in schools. These findings show that although the principal provides pedagogical direction and freedom to teachers, the integration of PM–KKA still requires alignment of understanding and implementation among the parties involved.

Supporting and Hindering Factors in the Implementation of PM–KKA The support of the school principal, collaboration among teachers, the presence of experienced teachers, and the availability of digital devices are supporting factors in the implementation of PM–KKA. However, the availability of facilities has not been matched by an equitable distribution of teacher competencies. The principal revealed that the opportunity to participate in training remains a limitation. "Not all teachers have had sufficient opportunities to participate in training on deep learning, coding, and artificial intelligence." (KS, Interview 11). In addition to the competency gap, teachers' readiness to face changes in learning also poses a unique challenge. "There are still colleagues who view Deep Learning and KKA as new changes that add to their workload." (DT, Interview 12). Unlike that statement, teachers who are members of the Curriculum Development Team view Deep Learning as an improvement of the learning practices in the previous curriculum. This difference in perspective indicates that teachers have varying levels of acceptance toward changes in learning. In addition, the limitations of internet and electricity networks also pose challenges in the utilization of digital devices. In facing these challenges, the principal directed teachers to utilize learning communities and peer mentoring as a means of problem-solving. Nevertheless, the equalization of understanding through mentoring still faces challenges as conveyed by the implementing teacher. "The challenge is how to ensure that the understanding conveyed back to colleagues remains the same and can be applied in the classroom." (GP, Interview 12). These findings indicate that the challenges of school leadership do not only lie in resource provision but also in change management, alignment of understanding, and consistency of learning practices. Therefore, continuous mentoring and evaluation become necessary in managing the integration of PM–KKA according to the school's conditions.

DISCUSSION

The research results show that the principal's leadership in integrating PM–KKA is not only oriented toward the implementation of educational policies but also toward managing changes in learning. Program planning, role distribution, teacher empowerment, and academic supervision reflect the characteristics of instructional leadership that prioritize learning. These findings are in line with Abdurrahman, Hasanah, & Sukirman (2026), who emphasize the interconnection between learning direction, teacher empowerment, openness to innovation, and continuous supervision in realizing meaningful learning. However, in the context of PM–KKA integration, school principals are not only required to direct pedagogical changes but also to manage teachers' readiness in facing technological developments. Empowering teachers through learning communities and peer mentoring shows that competency development does not entirely depend on the individual capacity of the school principal. These findings are in line with Santosa (2022), who emphasizes the

importance of planning, academic supervision, and collaboration in the development of teacher professionalism. In this study, the principal utilizes the diversity of teachers' competencies as a source of collective learning. Nevertheless, this strategy still faces challenges in ensuring the equitable understanding and consistent implementation of PM–KKA. Therefore, teacher empowerment needs to be accompanied by an evaluation mechanism that is not only oriented toward program implementation but also toward the quality of learning practices. The gradual and adaptive integration of PM–KKA demonstrates the connection between instructional leadership and digital leadership. Hasanah & Mohd Yusoff (2024) emphasize that digital leadership is related to the ability to develop an innovation culture, face changes, set strategic directions, and utilize technology. In this study, the principal gives teachers the freedom to adjust the use of technology to align with learning objectives and student needs. Deep Learning is placed as the pedagogical foundation, while coding and artificial intelligence complement the learning process. The unplugged coding approach is also relevant to the research by Dağ et al. (2023), which shows the potential of non-digital device learning in developing computational thinking skills among elementary school students. This shows that digital leadership is not solely related to the provision of technology, but also to the pedagogical management of its utilization.

The use of artificial intelligence as a teaching aid demonstrates an effort to integrate technology without neglecting the professional role of teachers. These findings are relevant to Chiu et al. (2023), who identified various opportunities and challenges in the use of artificial intelligence in education. However, the differing accounts from informants regarding the use of AI by students indicate the need for alignment in understanding at the educational institution level. In this context, the principal needs to maintain a balance between the freedom of teachers to innovate and the clarity of technology usage direction, especially concerning age appropriateness, ethics, and learning objectives. The gap in teacher competencies, limited infrastructure, and varied acceptance of change indicate that the integration of PM–KKA is not only a pedagogical and technological issue but also a matter of school organizational management. These findings are in line with Ambarwulan (2025), which shows that teachers' knowledge of Coding and Artificial Intelligence has not yet been fully matched by implementation readiness. Sulistyo & Tanesab (2026) also show the diversity in the implementation of Coding and Artificial Intelligence policies due to differences in school conditions and readiness. In the context of this research, the principal strives to overcome these obstacles through teacher empowerment, learning communities, and peer mentoring. The strategy reflects efforts to adapt to the resource limitations of the school. From the perspective of program implementation, Fixsen et al (2025) emphasize the importance of planned capacity development and organizational support in the execution of educational change. The findings of this study show that school principals have been striving to develop organizational capacity through role distribution, mentoring, supervision, and learning reflection. However, the existence of these mechanisms is not yet sufficient to prove the effectiveness of program implementation. The principal needs to strengthen evidence-based evaluations so that follow-up is not only oriented toward the implementation of activities but also toward the quality and consistency of the integration of Deep Learning, Coding, and Artificial Intelligence in learning practices. The novelty of this research lies in the conceptual synthesis of school principal leadership that connects program management, teacher empowerment, and learning improvement with the integration of Deep Learning, Coding, and Artificial Intelligence within a single educational unit context. The synthesis results in a conceptual framework of leadership characterized by being collaborative, adaptive, and pedagogically oriented. These three characteristics demonstrate the connection between instructional leadership and digital leadership in managing changes in learning at the elementary school level. Theoretically, this research expands the understanding of school principal leadership in the context of integrating pedagogical and technological innovations. Practically, the

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research findings provide implications for school principals to strengthen role distribution, equitable teacher competencies, alignment of understanding, and evidence-based evaluation. The integration of technology needs to be positioned as part of the effort to achieve pedagogical goals, not as a learning objective in itself. This research is limited to one educational unit involving four informants and using interview data. Therefore, the research results represent the experiences and perspectives of the informants and are not intended to measure the effectiveness of the principal's leadership or the impact of the PM-KKA integration on student learning outcomes. Subsequent research can involve several educational units and use observation and document analysis to obtain a more comprehensive understanding of the relationship between leadership strategies and learning practices.

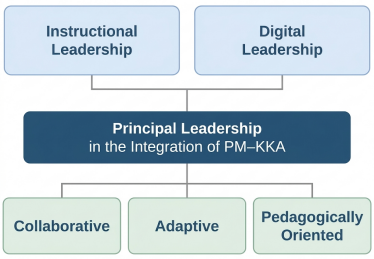


Figure 5. Conceptual Synthesis of the Novelty of Principal Leadership Research in the Integration of PM–KK

From this process, we formulated three characteristics of school principal leadership in integrating PM–KKA, namely: Collaborative: involving and empowering teachers. Adaptive: adjusting program implementation to the conditions and readiness of the school. Pedagogically oriented: prioritizing learning objectives over mere technology use.

4. CONCLUSION

The principal's leadership in integrating Deep Learning, Coding, and Artificial Intelligence at SD Negeri 011 Balikpapan Tengah has collaborative, adaptive, and pedagogically oriented characteristics. These characteristics are reflected in program planning, role distribution, teacher empowerment, peer mentoring, as well as supervision and learning evaluation. The integration of PM–KKA is carried out gradually, taking into account the needs of the students, the readiness of the teachers, and the conditions of the school. Nevertheless, the gap in teacher competencies, limited infrastructure, and differing understandings of technology use remain challenges in its implementation. This research produces a conceptual framework that connects instructional leadership and digital leadership in managing learning changes in elementary schools. Therefore, school principals need to strengthen the equitable distribution of teacher competencies, alignment of understanding, and evidence-based evaluation to support the sustainability of PM–KKA integration.

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