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Pedagogical Content Knowledge in Action During Problem-Based Learning: A Qualitative Analysis of Teachers' Facilitation and Classroom Regulation

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Abstract: Informed through Shulman's Pedagogical Teaching Knowledge (PCK), this study further explores how teachers acquire and utilize PCK, while enriching research on PCK and Problem-Based Learning. In these environments, collaboration and guidance, as well as teachers being responsive, are central. Lay of knowledge in the literature is particularly prevalent in qualitative work. Not a lot of studies "have really looked at how teachers 'practice' the teacher professional knowledge that they hold, through interaction as they go through a classroom episode and then through reflection on those practices." By putting reception teachers in behaviour in classrooms, in PBL scenarios, through the lens of PCK, this study conducts a MAXQDA analysis of the transcription of records of classroom transcripts and observational data. By positioning teachers' guidance strategies, emotional scaffolding, and situational regulation within the PCK 'sphere', this study aims to clarify what constitutes teachable knowledge of a subject to teachers as a collaborative opportunity. This also theoretically redefines the "space" of subject teaching knowledge, making it applicable to PBL teaching. Methodologically, we show qualitative coding and triangulation, and how they are used to build the argument on teacher knowledge.

Keywords: Problem-Based Learning, Pedagogical Teaching Knowledge, Qualitative Analysis, MaxQDA.

1. Introduction

Problem-based learning (PBL) has gained a foothold across disciplines, encouraging aspects of student-centered inquiry, collaboration, and critical thinking (Hmelo-Silver, 2004). PBL activity requires teachers to adopt new roles as "facilitators" and "guides" and co-constructors of their students' learning rather than merely "knowledge transmitters", with implications for what "professional knowledge" looks like as illustrated in teacher behaviour. While PBL as an approach has been studied as it relates to students, teacher behaviour and the kinds of professional knowledge that comes into play in this student-centric method is less frequently noted (Barrows, 1996; Hung, 2011). One particular concept useful to study teacher behaviour is Pedagogical Content Knowledge, or PCK, a term proposed by Shulman (1986, 1987). PCK emphasizes the importance of the blending of the subject matter knowledge with pedagogy that uniquely qualifies teachers to make the knowledge in a discipline accessible to learners. Grossman (1990), and Cochran *et al.,* (1993), have elaborated on what constitutes PCK, coming up with more expansive measures of the teacher's knowledge. Seeming of considerable influence, PCK studies are largely done in the context of traditional, non-PBL instruction, leaving the observations not to address newer modes of pedagogy like PBL. Approaching the teacher behaviour of PBL in the broad discourse of PCK, this study seeks to address that gap.

In addition to PCK, other frameworks for describing and understanding teacher behaviour come from sociocultural theory (Vygotsky *et al.,* 1978), teacher agency (Biesta *et al.,* 2015), and reflective practice (Schön, 1983). Teacher agency highlights teachers' capacity to act on their own professional judgement in the face of fluid classroom dynamics. Reflective practice emphasizes the examination of oneself by teachers through their everyday engagement in the crafting of professional practice. Together with PCK these offer potential insights into teacher behaviour in a PBL setting that gets beyond the descriptive, and offers a theorized description and explanation. Methodologically, qualitative analysis tools like MAXQDA provide a means of systematically analyzing complex data

sources like interviews, classroom transcripts, and observational notes (Abrahama *et al*, 2025; Torkaman, and Jalilisadrabad, 2024; Guetterman, and James, 2023; Kuckartz, and Rädiker, 2022; Koka *et al,* 2021; Marín, 2020; Williams and Moser, 2019). Through coding approaches, such as open, axial, and selective coding, qualitative researchers can explore emergent themes and build models of teacher behaviour that are determined by, and grounded in, the data (Corbin and Strauss, 2015). Unfortunately, existing studies often provide technical descriptions of software rather than demonstrate how qualitative analysis in particular provides strong support for or could illustrate theoretical claims. This study aims to fill that methodological gap using MAXQDA, not merely as a technical tool, but to provide a means of analyzing exactly how the use of "content knowledge" and "pedagogical knowledge" play out in the study of teacher behaviour.

The originality of this work lies in the theoretical contributions relating to the uses of PCK and similar frameworks to the study of teachers' PBL practices, particularly as multiple dimensions of professional knowledge are reflected in teachers' facilitation strategies, emotional scaffolding, and regulation of context. Methodologically, it demonstrates how qualitative coding and triangulation of multiple data sources can increase transparency and rigor in analyses. Empirically, it provides insight into teachers' adaptive practices in supporting collaboration and promoting collaborative problem-solving, thus contributing to teachers' adaptability learning in PBL contexts. Based on the foregoing statements, the following research questions are proposed.

(1) How does teachers' subject teaching knowledge-particularly their tactical or practical pedagogical knowledge-translate into situational behaviours within PBL contexts?

(2) How do the intersections of teacher knowledge, collaborative skills, and adaptive practice emerge qualitatively in PBL settings?

By posing the questions in these specific terms, this study addresses a significant void in the literature, theoretically and practically contributing to the fields of teacher education and the pedagogy of PBL. This research provides an answer to calls for greater engagement between theory and the real world of teacher behaviour, whilst also advocating a research agenda into how frameworks of professional knowledge can inform more innovative practice.

2. Literature Review: MAXQDA in Educational Research

2.1 Development and Research Capabilities of MAXQDA

MAXQDA is a qualitative and mixed-method program that is, turns out, popular across social sciences, education, psychology, public administrative etc. (Woolf *et al.,* 2017; Ruan, 2019; Marjaei, Ahmadianyazdi, & Chandrashekara, 2019). Described in glowing terms, MAXQDA has a pretty user interface as well as serious firepower generated in the engine behind it. The range of stuff that can be coded and analysed is vast, from interviews to transcripts, to open-ended responses to policy documents, to categorisation in memoir writing, and so on (Woolf *et al,* 2017; Marjaei *et al,* 2019). MAXQDA was employed to conduct structured content analysis of classroom video transcripts, teacher interviews, and course design documents. Through coding, categories such as cognitive scaffolding and emotional support were identified, while visualization tools were used to illustrate the evolution of teacher behaviour across instructional phases. This methodological approach demonstrates how MAXQDA can serve not merely as a technical program but as an analytical framework that bridges empirical data with theoretical constructs, enabling insights into teacher behaviour within PBL instruction. Together, these features provide a robust framework for qualitative and mixed-methods research, supporting integration strategies such as result-based, data-based, and transformation-based analysis (Guetterman & James, 2023; Kuckartz & Rädiker, 2022). By combining coding, visualization, and integration tools, MAXQDA facilitates rigorous inquiry and strengthens the connection between theoretical perspectives and empirical findings.

2.2 Empirical Studies Utilizing MAXQDA

Educational Studies reflected increasing methodological diversity and critical engagement with instructional innovation and student learning. In mathematics education, Schettino (2016) proposed a reflective approach with feminist and relational perspectives, combining problem-based learning with relational pedagogy to emphasize

student voice, agency, and equity. Shirani *et al.* (2016) examined components and institutional barriers to effective teaching, generating a systematic framework through qualitative content analysis. McIntyre-Hite (2016) employed the Delphi method to establish principles for competency-based education (CBE), highlighting both consensus and divergent perspectives. Dreier-Wolfgramm *et al.* (2018) adopted a mixed-method design to investigate learning outcomes, though limitations such as a small sample size reduced external validity. Attepe Özden and Tekindal (2019) explored student responses to instructional methods and teacher–student interaction, producing coherent themes that demonstrated analytical rigor.

Marín (2020) applied an e-portfolio model, mixed survey, and qualitative data to note contributions to educational equity and institutional critique. Tehran *et al.* (2021) used qualitative content analysis with attention to credibility and transferability, while Estaji and Fatalaki (2022) comment on lean a thick description and member checking to reinforce rigor in their work. Soebagyo and Amalia (2022) studied digital tools for mathematics teaching in relation to 21st century skills. Waity, Sellon, and Williams (2023) studied student reflections for themes of their continuing skill development, deep understanding, and meaningful experience, particularly noting attention to being team players and developing social responsibility. Weixelbraun *et al.* (2024) introduced the concept of the "protagonist role" in learning, connecting participatory design to OECD frameworks of transformative competencies. Ullrich *et al.* (2024) applied document analysis to student presentations, situating participative observation within pedagogy and institutional ethnography. In another study, Abrahama, Krishnappa, and Federico (2025) investigated healthcare professionals' perceptions of patient safety culture in India, identifying key themes, including managerial support, staff shortages, and organizational learning. Pius and Murugan (2025) studied senior Customs House Agents adapting to digital transformation, revealing how institutional systems such as ICEGATE and RMS shape customs clearance practices.

Ahmad (2025) examined communication dilemmas of deaf students, emphasizing the role and limitations of Pakistan Sign Language interpreters. Humble (2025) conducted a longitudinal study on qualitative research and QDAS use in family science journals, noting increased adoption but cautioning against uncritical reliance on automation. Star, Ringaert, and Larcombe (2025) investigated HIV care journeys in an Indigenous-controlled study, using dual coding frameworks to uncover intersections such as stigma and racism. Milaré *et al.* (2025) explored mindfulness perception, identifying behavioural and emotional shifts and calling for greater methodological transparency. Collectively, these studies demonstrate the methodological rigor and diversity of recent educational and institutional research. They highlight how qualitative tools such as MAXQDA support systematic coding and thematic analysis without overshadowing theoretical contributions, thereby advancing understanding of teacher practice, student agency, and institutional adaptation in varied contexts.

2.3 Inter-relations of MAXQDA, PBL, and Administrative Law

Scholars have long discussed the classification and application of problem-based learning, with Barrows (1986) emphasizing the centrality of "problem" as both the launching point and driver of knowledge construction. Rooted in constructivist and cognitive psychological theories, PBL encourages learners' active inquiry, collaboration, and problem-solving in authentic contexts, ultimately fostering self-directed learning and critical thinking. Effective PBL design requires ill-structured problems that stimulate curiosity and exploratory impulses, often derived from real-world contexts. These processes reshape not only student learning but also teacher instructional procedures.

Empirical studies reinforce this transformation. Li and Tsai (2018) documented a Taiwanese mathematics teacher's shift toward guiding inquiry and scaffolding knowledge, driven by reflection and institutional support. Wang (2021) reported that PBL enhanced preservice teachers' motivation, teamwork, and reflective practice, while also influencing teacher trainers' instructional identity. Such findings underscore how PBL impacts both student learning and teacher behaviour. Qualitative research tools such as MAXQDA have been employed to analyze these changes, supporting systematic coding of teacher language, feedback strategies, and classroom interaction. Rather than focusing on technical features, scholars emphasize how MAXQDA enables transparent thematic analysis and integration across diverse data sources, revealing tensions between traditional pedagogy and PBL principles (Williams & Moser, 2019; Cernasev & Axon, 2023; Lee *et al.,* 2024).

In legal education, PBL has been applied to administrative law, reframing abstract doctrines into problem scenarios such as "special power relations between teacher and student" or "academic dishonesty in military universities" (Lin, 2017; Chang, 2021). These approaches encourage students to construct legal meaning through inquiry and reasoning. Qualitative analysis of classroom discourse, interviews, and student work—supported by tools like MAXQDA—facilitates the development of typologies of teacher behaviour and decision-making logics. Overall, the synthesis of PBL, teacher behaviour, and qualitative analysis has created a rich theoretical and methodological foundation. This integration advances understanding of how teachers adapt to student-centered learning, how reflective practice emerges in diverse contexts, and how systematic qualitative inquiry contributes to replicability and transparency in educational research.

2.4 Pedagogical Content Knowledge and MAXQDA

Pedagogical Content Knowledge "PCK" first appears in Shulman (1986) as a kind of teacher knowledge. While each teacher teaches a subject matter, the teacher must bring in knowledge of that subject matter, along with knowledge of teaching and learning, to make decisions and adapt materials for the students' learning. Shulman's (1987) elaboration of his framework highlighted the professional dimension of teacher knowledge and laid the background for later empirical measures of PCK. Together, these studies extended research on teachers' representations of disciplinary knowledge in forms accessible to their students. PCK can help researchers "make sense" of teacher behaviour and professional practice in qualitative inquiry. "Application of approaches like classroom observations and teacher interviews to the teacher's construction of practice" (as artfully presented in codifications like operationalizing PCK in qualitative MAXQDA) is where researchers can find the minimum of surrogate theoretical anchors as aspects of teacher knowledge at work.

Similarly, the present study tries to enhance the trajectory of studies on teacher behaviour and situate it in the context of PCK. By making use of MAXQDA to analyze multiple data sources, this study engages directly with Shulman and his extensions and try to demonstrate how teachers' facilitation strategies, reflections, and collaboration can be understood as reports of pedagogical content knowledge and to contribute to the ongoing debate about the role PCK occupies in today's teaching and what qualitative methods can do to ground theory.

This study invokes learning pedagogy, teacher behaviour, and qualitative software analysis in turn to ask where this contradiction arises from. The teacher behaviour enacted at that pedagogical site holds keys to the quality of acceptance, of facilitation, of the investment of earnest, goodness and effort in there, of this interaction work at play and of the style of the other means of engagement and guide. Those behaviours forged together explain by the qualitative software reading, categorizing, and visualizing data. Pedagogy provides the ocean of a sea context, the teacher's behaviour, the kind of ship in which to sail it, the qualitative software, and the tools to map the wanderings. The model is theory (PBL), practice (teacher action), and method (research-based software analysis), speaking conceptually.

3. Research Design and Methodology

3.1 Research Context

The purpose of this study is to explore the interactional styles and behavioural patterns of teachers in a problem-based learning classroom context, using MAXQDA for qualitative data analysis so that a contextually rich and theory-driven model of teacher behaviour can be developed. The research design and methodology are discussed in terms of four dimensions: conceptual framework, sources of data, analysis procedures, and procedures for trustworthiness. The study implementation period is from August 1, 2024, to July 31, 2025.

The study adopts a qualitative research orientation and, in order to investigate teachers' language development and use, teaching strategies, and behaviours as they managed the context of the PBL, it utilized classroom observations, interviews and analysis of the relevant teaching materials. The data were collected in three higher educational settings where the PBL methods and process were well established. For data collection, six experienced PBL teachers were purposefully sampled to take part in the study. The six teachers selected as participants were in-service teachers who were all trained professionals that had some experience with PBL, and thus, a purposive sampling design was used since the selection of interviews should be done on the basis of

professional knowledge, experience, and objectives of research (Patton 1990). Their experience in practice and also experience in applying elements of PBL meant that PCK theory could be more easily employed in showing what sort of expertise helps stimulate interest and engagement in students. The teachers were invited to participate in the research via formal invitations distributed through their university processes. There was an effort to achieve representation across multiple disciplines; however, all the teachers were experienced PBL facilitators. All teacher participants received informed consent before any data collection began. To ensure confidentiality and anonymity, participants were assigned pseudonyms; further, any identifiable characteristics were not included in the transcripts or findings, ensuring participants' identities remained protected.

Data were gathered in three categories: (1) Audio-recorded classroom observations/transcripts were used to see what the teachers did, (2) The instructional design documents and course syllabi provided context in which to place the teachers' practices. The analysis conducted with the aid of MAXQDA consisted of four stages: (1) Data analysis, using coding to identify and annotate verbal and non-verbal teacher behaviours and strategies for regulating instructional practice; (2) The identification of teacher behaviour and the categorization of the data into thematic clusters; (3) The development of a comprehensive model of teacher behaviour based upon the relationships between groups of teacher behaviours, types or strategies that the teacher uses, and the context in which the teacher practices; and (4) The use of visualization tools and modules in MAXQDA for cross-case comparison and the validation of the thematic cluster identified through qualitative analysis of the coded data in MAXQDA, resulting in theoretical saturation of the themes identified in MAXQDA. This methodological approach results in a more detailed picture of the teacher in the PBL environment and informs the development of empirically based instructional models for teacher education programs.

3.2 Participant Roles and Interaction Dynamics in PBL Scenarios

In PBL courses, the roles and interaction sequences of participants are key to learning outcomes and also form the basis of the methods of knowledge construction and instructional design. Participants include students, teachers, and sometimes outside experts, each of these groups having dynamic and complementary roles within the framework of PBL. Students become involved in learning through action and collaborate in an active way. Learners are not passive recipients of knowledge but active agents in solving problems. The authentic, ill-structured problems are designed to involve students in data collection, hypothesizing, planning solutions, and reflecting upon these processes in an interactive way. This process depends on the success of the development of critical thinking, communication, collaboration, and self-directed learning skills. Empirical research has shown that PBL has a positive impact on students' motivation, personal engagement, and learning attitudes.

Teachers move into the roles of facilitators of learning and designers of contexts. Their role becomes very much one of directing students in the clarification of problems, the timeliness of feedback, facilitating interaction in groups, and creation of an environment in which to learn. Teachers' use of language, questioning strategies, and feedback have considerable effect on the students' learning pathways and their construction of knowledge. Some research further indicates that this change of role also leads to teachers' pedagogical reflections and professional development. In some course designs, these dynamics are enhanced by the presence of outside experts or practitioners, who add to the realism of the problems, render connections to other fields of study more possible and feasible, and allow students to integrate and apply knowledge in more complicated and socially useful circumstances. The multi-participant dynamics not only enhance the social interactions of the learners but also increase the vocational and professional orientation of the curriculum.

This study includes six interviewees to capture diverse teaching styles, subjects, and experiences. Such variety enhances validity by avoiding reliance on a single viewpoint. The sample size supports theoretical saturation, where no new insights emerge with further data. Six participants provide both breadth and depth, manageable for coding and triangulation in MAXQDA. Comparisons across cases strengthen credibility and transparency of findings. Triangulation highlights consistent teacher behaviours and supports theoretical arguments. While not aiming for statistical generalization, six participants sufficiently represent PBL teachers in higher education. The interactions among the participants in the PBL courses create a dynamic learning ecology. The exploration and agency of the students, the strategic facilitation and contextual design by the teachers, and the involvement and integration of external resources progressively create deep constructions of knowledge and provide an activation of learning

momentum. This structure is consistent with current educational demands of a learner-centred and contextually interactive pedagogy and provides rich sources of both theoretical and practical points of reference for curriculum design and instructional research.

Regarding the practical implications of this study, teachers explicitly incorporated PBL facilitation strategies into their designs. For example, classroom design could include instructing teachers in contextualized practice, learning to scaffold student inquiry, managing group dynamics, and tying the PBL task to curriculum objectives. Incorporating reflection into activities allows teachers to tie their facilitation behaviours to PCK, and thus build on their pedagogical theory for effective practices. Situating PBL facilitation in authentic classroom environments, teacher educators radically improve upon general advice for practical strategies that impact curriculum.

3.3 Methodological Clarification: Grounded Theory and Triangulation

3.3.1 Methodological Orientation

This study is qualitative in orientation, drawing upon aspects of the grounded theory approach (Glaser & Strauss, 1967; Corbin & Strauss, 2015). The general study of course records reflects the influence these authors have had on the process of obtaining and manipulating the various codes open, axial, and selective.

3.3.2 Triangulation Strategies and Data Integration

To enhance the validity of the research, this study employed triangulation (for the same topic) or cross-referencing (across sources). In this analysis, classroom transcripts provided authentic data on teacher-student dialogues, interviews provided data on teachers' own beliefs about their teaching practices, and video recordings of curriculum design provided relevant documentary data. Integrating three sources (rather than two) as a basis for summarizing and generalizing the findings (ensuring the research results are supported by multiple pieces of evidence) enhances the credibility and rigor of the analysis. This study compared these three sources and employed a method we call "cross-referencing" (using the MAXQDA term "X" in the design) to examine the convergence and divergence of topics and the cross-cutting of the code they imply. We constructed comprehensive definitions and arguments based on categories cross-referenced across two or three sources; ultimately reaching analytical saturation, thus ensuring the credibility of the research. Images can help us understand (and convey) the content of a lesson.

Table 1. Matrix for Triangulation

Teacher Behaviours	Classroom Transcripts	Interviews	Instructional Documents
Facilitation Strategies	Evidence of questioning, prompts, group guidance	Teachers' reflections on guiding inquiry	Syllabi emphasize collaborative tasks and open-ended problems
Emotional Scaffolding	Observed supportive language, encouragement	Teachers describe importance of motivation and empathy	Course design includes reflective activities and peer support
Contextual Regulation	Timing of feedback, structuring group work	Teachers explain rationale for adjusting activities	Documents show planned phases of inquiry and assessment
Collaboration Skills	Student group interactions facilitated by teacher	Teachers highlight teamwork and communication	Assignments require cooperative problem-solving
Adaptive Practices	Adjustments to student responses in real time	Teachers discuss flexibility and professional judgment	Curriculum outlines contingency strategies for diverse learners

Source: Flick (2018), supplemented by the author's textual adjustments.

Below is an example of a matrix used in this study to illustrate insights, focusing on teacher behaviours (facilitation strategies, emotional support, situational regulation) rather than research priorities (collaborative skills, adaptive practices, professional development). This matrix, at least for this study, conveys the logic of whether the data coding conforms to the concepts followed. Facilitation, emotional support, and situational regulation must be based on empirical material of what is happening in the classroom (transcribed texts must be presented verbatim) and interpreted within the relevant MAXQDA coding framework; triangulation of participants helps improve the transparency of the analysis and validate each theme. The above discussion is briefly summarized in the table below:

This triangulation strategy is illustrated in this matrix as teacher codes were mapped to categories of teacher behaviour, with the data coming from the three types of data sources (i.e., classroom transcripts, interviews, and instructional documents). The rows represent the key codes and categories of teacher behaviour as they were coded in the analysis, and the columns represent the source of data. Each cell indicates whether the data from each data source supported or contradicted the theme, thus providing a way to see where findings converge and diverge in the whole dataset. By mapping emotional scaffolding, contextual regulation, facilitation strategies, collaboration skills, and adaptive practices to a variety of types of evidence, this matrix describes an open and thorough way to collect data with the aim of reaching conclusions about how to best support students engaged in PBL instruction. The triangulation approach and the way to bring together findings across varied forms of evidence help to solidify the rigor and credibility of the analysis, and ensure that any conclusions made about teacher behaviours in PBL contexts are well-grounded in multiple strands of corroborated evidence.

3.4 Conceptual Framework

The following conceptual framework (see figure 1) guides this study and incorporates Pedagogical Content Knowledge, Teacher Agency, and Reflective Practice as theoretical perspectives, each of which interacts with how teacher behaviours in problem-based learning are informed by problem space behaviours and recorded in MAXQDA, allowing actions to be coded, triangulated, and visualized.

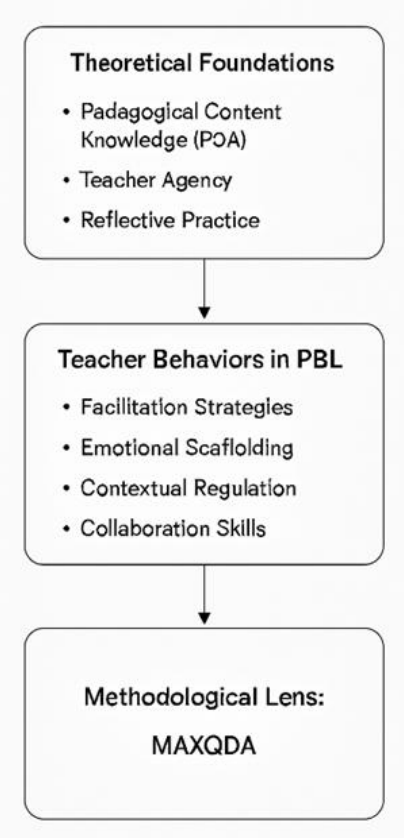

Figure 1. Conceptual Framework of the Study
Source: Shulman (1986, 1987) and Cernasev & Axon (2023)

This figure highlights the predominant assumptions underpinning our study. Pedagogical Content Knowledge, Teacher Agency, and Reflective practice serve as the theoretical foundations represented here. Through these, teacher behaviours are determined in PBL (the facilitation strategies teachers adopt, their willingness to scaffold emotional process, how well they regulate context in PBL, their 'collaboration skills',etc.). These theoretical underpinnings are connected to methodology – MAXQDA (coding, triangulation, & visualisation) links theory and practice, theory and 'evidence present' in the videos.

The development of the teacher behaviour model is grounded in its contribution to theory. Situated within an established theoretical framework, this model augments existing work by marrying the PBL experience with the theory of PCK. In doing so, this study demonstrates how teachers' behaviours (that are cultivated through their training and school practice) act as mediators between theory and student interest.

4. Analysis and Process Explanation

This study uses MAXQDA's analytical coding structure and visualization modules to analyze teacher coding, aiming to identify facilitation, feedback, and moderation patterns in the classroom in greater detail, thereby contributing to a deeper understanding of the dynamics of instruction in problem-oriented learning situations. The relevant analysis diagram is shown below.

4.1 Coding Process in MAXQDA: Data Analysis and Classroom Transcripts

This figure illustrates how MAXQDA's document viewing interface supports the analysis of interview data, specifically focusing on pupils' engagement with Problem-Based Learning Solution Record-sheets and their feedback. The displayed document, titled Interviewee A, is part of a broader investigation that includes other participants such as Interviewee B. The content is organized around two central themes: one addresses Interviewee B's reflections on the design and implementation of the record-sheets, while the other explores how these sheets influence pupils' learning processes and case-based discussions. The interview reveals that the record-sheets guided students in systematically analyzing and solving problems, deepening their understanding of legal practices and judgments. Through case work, the pupils learnt both to think things out and to express things on their own behalf; they developed critical reasoning and forensic argumentation in matters of their environment.

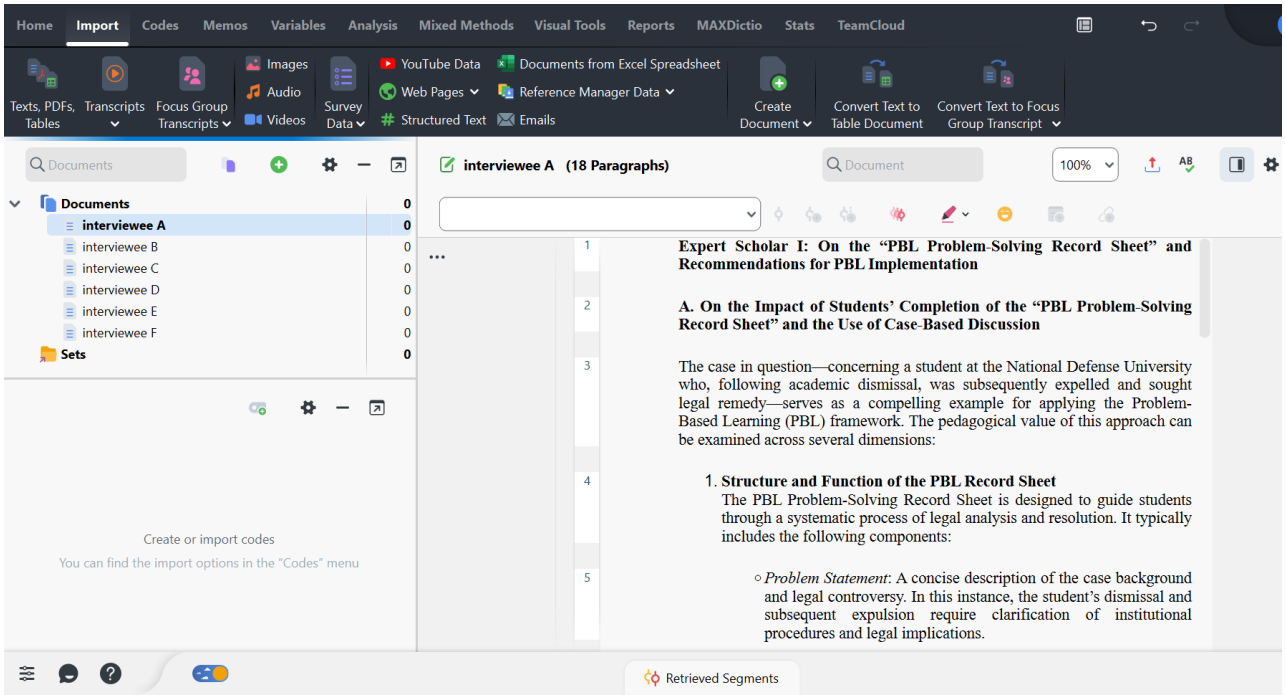

Figure 2. Interview Transcript Input and Coding Process in MAXQDA

Source: Interviewees' Transcript from A to F

The figure also suggests the power of MAXQDA to code text in real time, which enables the researcher to code, comment on, and categorize their data expediently. With frequency analysis, matrix comparisons, and a mind-mapping program, the software lends aid to horizontal analysis across subject groups. The software extends the notion of teacher behaviour as a function of pupil response. Here are quoted excerpts from transcripts of six interviewees. According to Interviewee A's opinions:

This case of the student from the National Defense University, who, after academic disenrollment, was later expelled from school altogether, seeking a remedy, seeks to invite the ideal of Problem-Based Learning (PBL) to grow in disciplinary study. Its utility for pedagogy may be approached from different dimensions.(Code A)

In other words, following Interviewee A's discussion of moving beyond the walls of the classroom to change the world, Interviewee B takes us out into the world through social media.

According to Interviewee B's opinions:

Students might be encouraged to share case studies and insights on social media, so as to promote reflective engagement with legal and administrative issues in a public forum.. (Code B)

While Interviewee B takes learning outward, Interviewee C turns attention inward - and looks at the instructor's classroom techniques.

According to Interviewee C's opinions:

The teacher cares and pays close attention. Everything is straightforward in his explanations, so people follow the course well, and they understand the core ideas in administrative law. I really enjoy that he uses stories as teaching tools. Lends accessibility to the doctrines. And the way he opens the floor to student involvement and promotion of inquiry creates a cool vibe in the room. (Code C)

Following the high praise from Interviewee C about teaching techniques, consideration is next given to ways of looking at the materials by Interviewee D, who speaks about shortcuts and what needs to be paid attention to more carefully.

According to Interviewee D's opinions:

I really enjoy the guest speakers and the commentaries on news items in the class. They help remind me of where I can see administrative law proving to be so useful. In the textbook and in the teaching materials in general though, I feel like 101's of official documents and judgments haven't received as much attention, and I haven't actually studied the basic theories of the statutes as much as I should have. I think it would help us to include more focus on actually "learning that stuff," in clarity about text and legal speak especially." (Code D)

Finally, after Interviewee D's advocacy for more attention to language, Interviewee E encourages a broadening of case descriptions so that newbies can find the information to engage with. According to the Interviewees E's and F's opinions:

The case descriptions in the book are somewhat thematically succinct for real application, in a way only stat lawyers would get. More elaborated accounts would make things more understandable to get more people up to speed on laying the groundwork. (Code E)

The use of case studies has indeed sparked great interest among students in the course. (Code F)

When teachers use open-ended questions, students appear more involved in taking the test and solving problems; contextualized reconstruction or problem-oriented exercises are likely to enhance student motivation and participation. Investigative analyses build up, revealing not only the functional and contextual nature of teacher behaviour but also their tactical and coordinated functions in the PBL operations. It began with an open-ended coding of the interview transcriptions with MAXQDA; the open-ended coding was used to derive common teacher behavioural functions. The initial step, which concentrates of semantic units and behavioural connections, resulted in a coding that recorded teacher behaviour and clustered those behaviours across the transcripts into behaviours such as cognitive scaffolding behaviours, context regulation, and emotional support behaviours. With this work, it was possible to analyze where teacher behaviours did not track students and where the teachers were tracking and/or helping students literally get back on track.

4.2 Teacher Feedback: Teacher Behaviour

Additionally, the following is a photo from the MAXQDA training session, showing the instructor's feedback.

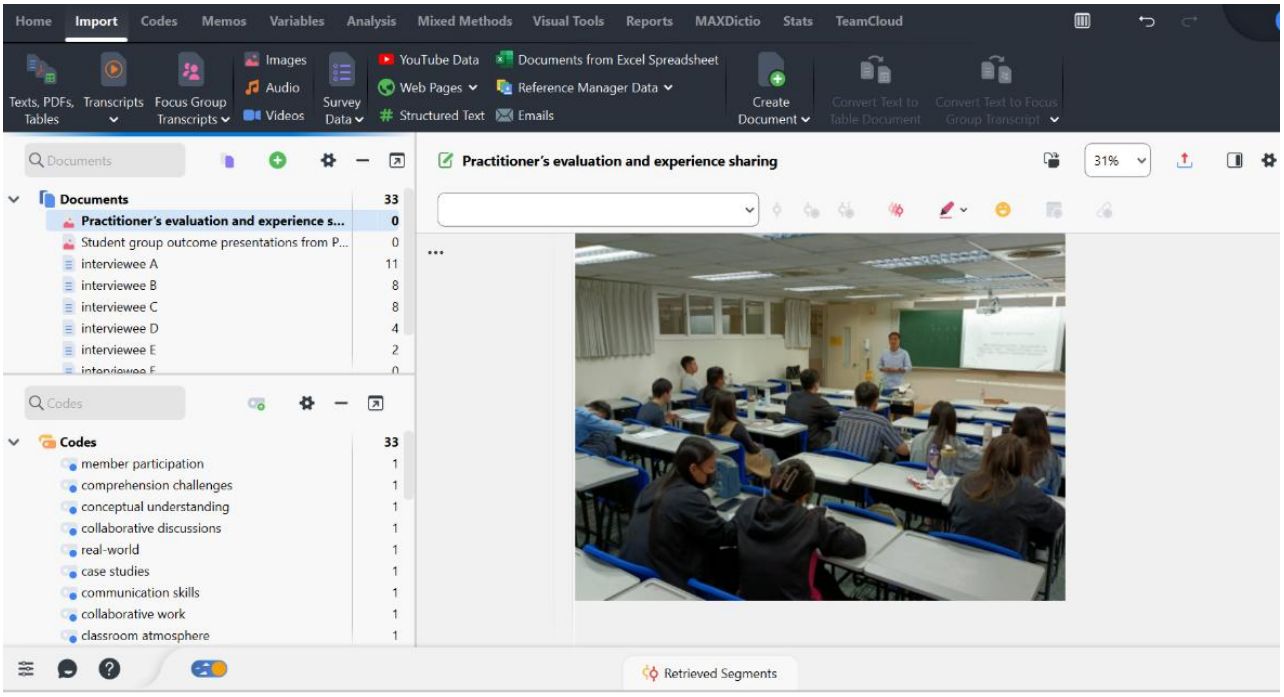

Figure 3. Expert Instructor Feedback
Source: Classroom photographs of students

This picture presents the working interface of MAXQDA for the treatment of both visual and textual material derived from instructional situations concerning the qualitative study of "Evaluation and Experience Sharing of Practitioners in the sphere of measurement of course worth." The document which is shown is that of a research project treating of classroom observation and pedagogic reflection. The figure exemplifies how MAXQDA can combine different texts, such as the transcript of our reflection, the coded added reflections, and even visual illustrations or additional data, within a single analytic framework. The actual mechanics of what MAXQDA allows is indeed important, but perhaps what is intertwined in that is the more significant point: Here is such a grounded place for coupling the study of the particulars of the classroom with theory, and thus strengthening the qualitative project of teacher education/teacher education researchers.

MAXQDA software displays classroom photographs showing students in naturally generated learning situations in front of teachers or presenters. This type of visual material can be encoded and integrated into textual materials, allowing researchers to connect the graphics of teaching behaviour, student responses, and the construction of spatial relationships. This encoding can then be applied again in MAXQDA through visualization tools such as mind mapping and matrix analysis, leveraging all the advantages of synthesis and theoretical construction. Thus, this interface shows the integrative power and working flexibility characterising MAXQDA, a great deal of work for mixed methods research with special reference to course evaluation, teacher professional development and student learning outcome evaluation.

4.3 Student-Based Group Report: Relationships between Groups of Teacher/Student Behaviours, Types or Strategies

Furthermore, the following image shows a MAXQDA screenshot of students' PBL group report. In PBL courses, student reports group more than simply serve as one form of outcome presentation, but would also represent an extension of the learning process as well as a reflection of it. It is through the operational interface of MAXQDA that a researcher can feed into the document, management, and codes will use a coding system, make a qualitative analysis of the students' performances and interaction patterns that existence within the group presentations.

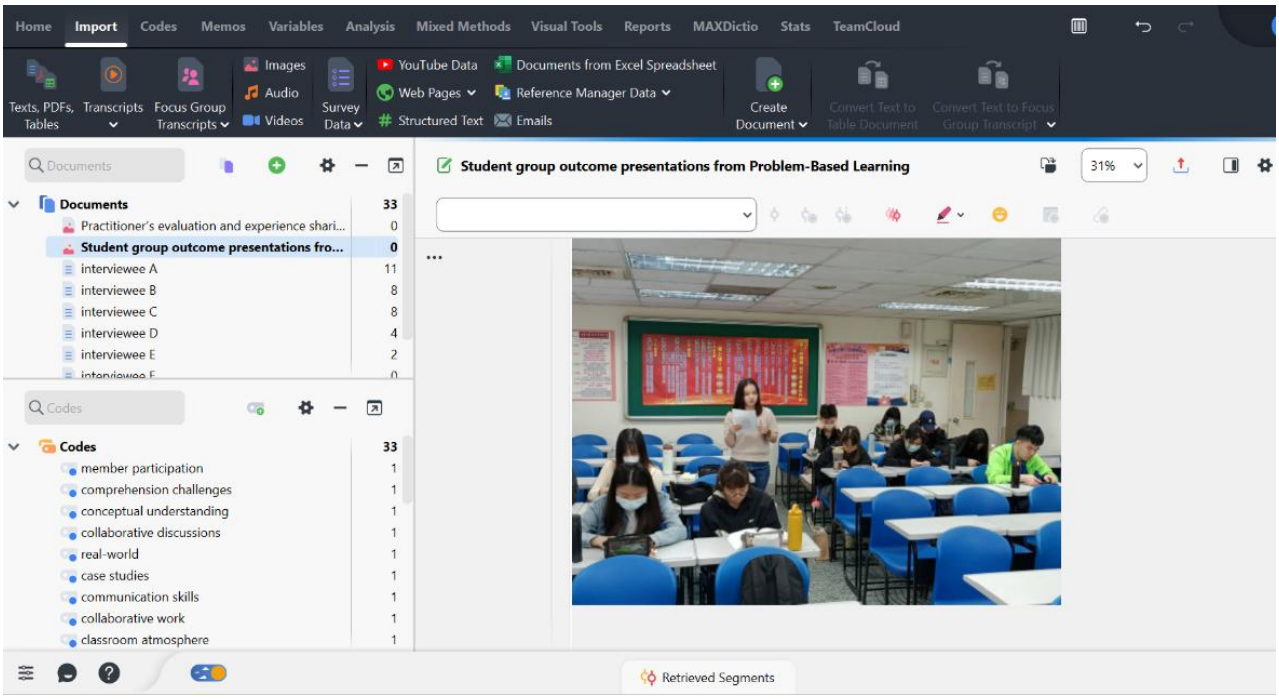

Figure 4. Student Group Report

Source: Student Group Report Image

For example, in the case called Student Group Outcome Presentations from PBL, the operational interface shows a picture of the classroom in which the students are seated in groups, with some in masks and a person presenting a presentation. The background of this operational interface contains a red bulletin board indicating a formal instructional environment.

In the example of Student-Based Group Presentations from PBL, the MAXQDA interface shows a classroom scene where students are seated in groups, some of them wearing masks, while one of them makes a presentation. The red bulletin board gives an indication that it is a formal instructional setting. The left side of the screen shows the document list and coding scheme demonstrating the coding framework used by the researcher. Codes were created to reflect themes that arose out of the reports, such as "member participation," "communication," "presentation skills," "problem solving," "critical thought process," and "self-directed learning."

These codes indicate the general thrust of the study in the students' expressive modes in collaboration of the in-depth reasoning process. The qualitative analysis of the group reports as this can integrate into them visual language associated with the use in the area of report preparation with text saved. The researcher may observe the way in which the students manifest through the use on their case studies, the synthesis of their work, and the way logical thinking and creativity have been exhibited between them in their presentations. The researcher may use the point tools of actual presentation that exist using MAXQDA, including mind mapping techniques or matrix analyses. Using both would insure cross group comparisons and integration of meaning. When this is then coupled with the development of teacher evaluation and comprehension factor, plus student evaluations, it further explores the instructional design feedback mechanisms plus the learning effect present in the case designs.

4.4 Word Trends: The Use of Visualization Tools

The Word Trends tool in MAXQDA allows researchers to visualize the frequencies and distributions of specific words in documents. This facility is most beneficial for time series and for following thematic development. This function of Word Trends gives the following visual output.

This visual shows the Word Trends function in MAXQDA in relation to education research in order to analyze the trends in word usage in relation to a number of documents. The trend is shown by a line graph, which depicts the trends in frequency of several key words such as student, PBL, critical, question, explanation, problem solving, teamwork, and engagement, which appear in various colors on the line graph.

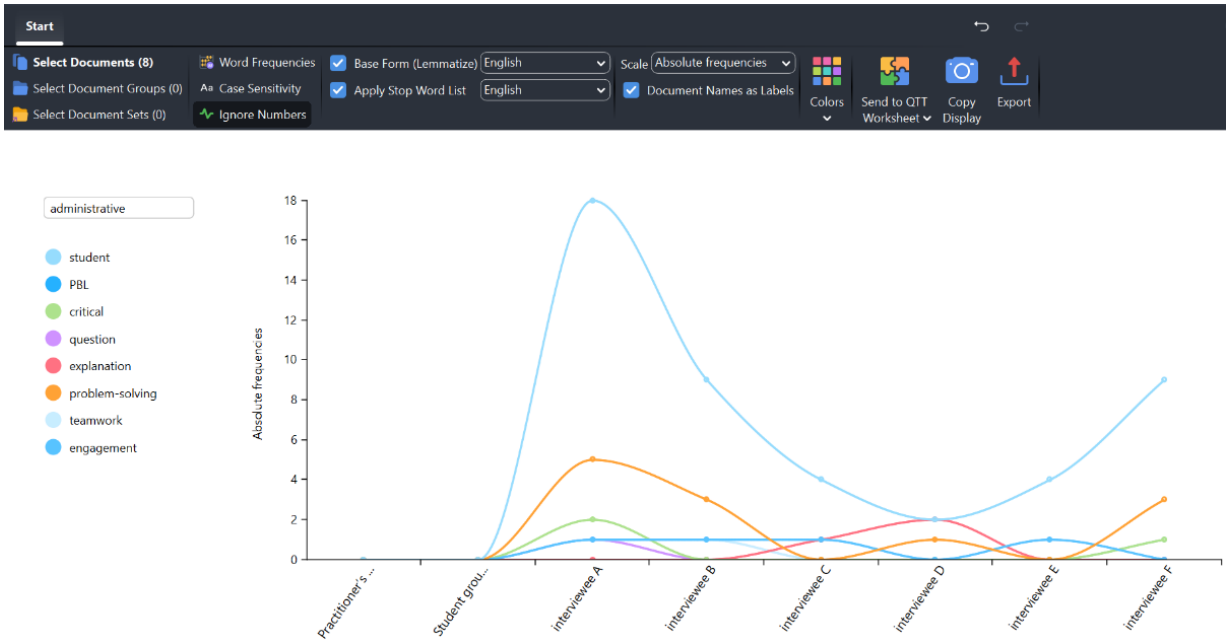

Figure 5. Word Frequency Trends (Word Trends)
Source: Compiled by the author using MAXQDA software

The horizontal axis depicts the documents under consideration (Interviewee A to Interviewee F), while the vertical axis points to the number of occurrences of the words used.

This type of visualization goes beyond simple counting and allows us to see points of emphasis across the different stages of the research/instructional process: an upward trend in "critical" and "problem solving" might imply a greater emphasis on analytical thinking in later documents, while persistent mentions of "student" and "engagement" may suggest that learner-centred pedagogy held sway across the board.

This illustration helps the education researcher to compare the distribution of the key expressions in the different texts, as well as their intensity, and is especially useful as an analysis of the patterns of language of the students' reports, teachers' comments, or classroom transcripts. For example, critical and problem solving may occur more frequently in one group's reports, which would indicate a better performance in the realm of critical thinking and problem-solving skills; similarly, fluctuations of engagement and teamwork will show children's participation patterns, and collaborative processes. This Word Trends function is particularly useful for course evaluation, analysis of student performance language and the assessment of thematic saturation of qualitative data.

4.5 Word Cloud: The Use of Visualization Tools

The use of the Word Cloud function in MAXQDA allows high-frequency terms in a text to be visualized quickly and effectively. It is especially well-suited to analyses of thematic schemes in interview transcripts, policy documents, or course materials. The steps to be taken to create a word cloud are as follows:

This figure illustrates a rendering resulting from the Word Cloud program used for analyzing keyword distribution within educational text or student feedback data. The central word cloud contains words in varying sizes and weights related to frequency; among the words appearing prominent are reflection, suggestion, feedback, material, course, student, understand, and discussion—all indicating considerable theme relevance within the data set. The Word Cloud not only provides a visual means of making sense of the text but also comprises a level through which qualitative analysis might occur by determining which concepts seem to be dominant, and to code the terms, and where in their individual texts they occur, and with what, appealing to overviews such as PBL or PCK.

This Word Cloud construction method is particularly suitable for thematic interpretation of course assessment, student reflection analysis, and instructional feedback.

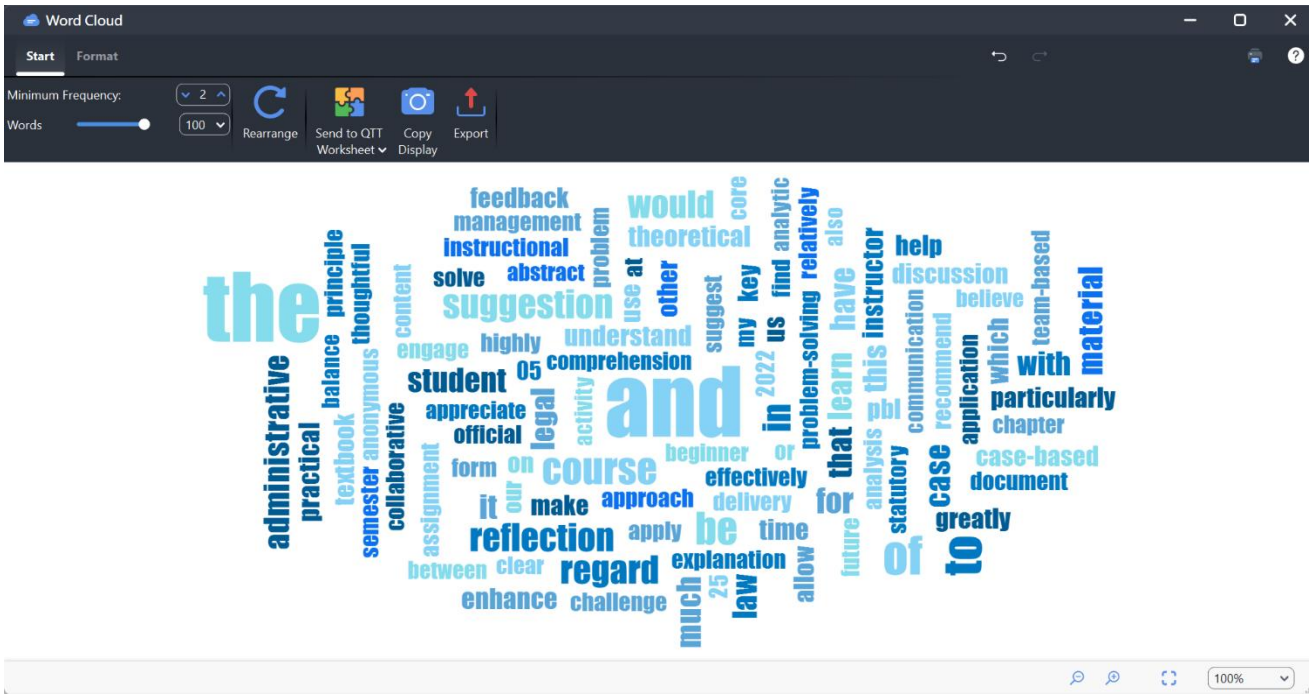

Figure 6. Word Cloud Visualization
Source: Compiled by the author using MAXQDA software

In terms of lexical features, the Word Cloud covers themes such as instructional design (e.g., teaching methods), student-centered learning processes and steps (e.g., understanding, explaining, assisting), student characteristics (e.g., beginners, students), and the connection between theory and practice (e.g., theoretical, practical, managerial). The sum of these words constitutes a semantic domain limited to the areas of learning comprehension and instructional feedback, enabling researchers to categorize and assess data based on common themes and language. After excluding meaningless function words such as "and" and "the," the four most frequently occurring words are "and," "reflection," "student," and "regard." This indicates that when using PBL in the classroom, our records of students (and their reflections) are about them.

4.6 Document Map: The Use of Visualization Tools

The figure shows the usage of the Document Map function built into the software MAXQDA for qualitative research. This is used here to display thematic similarities, as well as coding divergence between interview respondents through the use of a graphical display. The central scattergram represents six respondents (Interviewees A to F) indicated by colored dots. Each dot represents either the total thematic coding or variable values of one interview transcript, and the position of the dot indicates relative closeness to other respondents. The graph possesses no labeled axes since the emphasis is not on actual values, but on the relative position and patterns of clustering of the respondents.

The graph does not have labelled axes, since it is not concerned with numbers but the relative positioning (the gist of the visualization is interpretive, of the shapes of clustering, proximity, and dispersion, etc.), and thus indicates how qualitative coding can be captured with spatial diagrams to better grasp complex relations. Dots that seem to correspond closely may indicate similar response patterns to specific items, as for instance, understandings about PBL pedagogy, administrative law cases, or learning strategies. Dots that are scattered may indicate different bases of opinion or the influences of different roles and experiences.

The content analyses carried out here highlight some of the methodological advantages of the employment of MAXQDA in a situation involving the investigation of complex instructional interaction data; they also provide an orderly, systematic, contextual, and theoretical framework for the study of teacher behaviours in PBL settings. Future research may investigate the interlocking relationships between teaching style, adaptability to context, and student learning outcomes based upon a further mutual interplay between pedagogy and educational theory.

Based on the aforementioned description, this study further interprets teacher behaviours, PBL constructs, and Maxqda process methodological tools into the following figure.

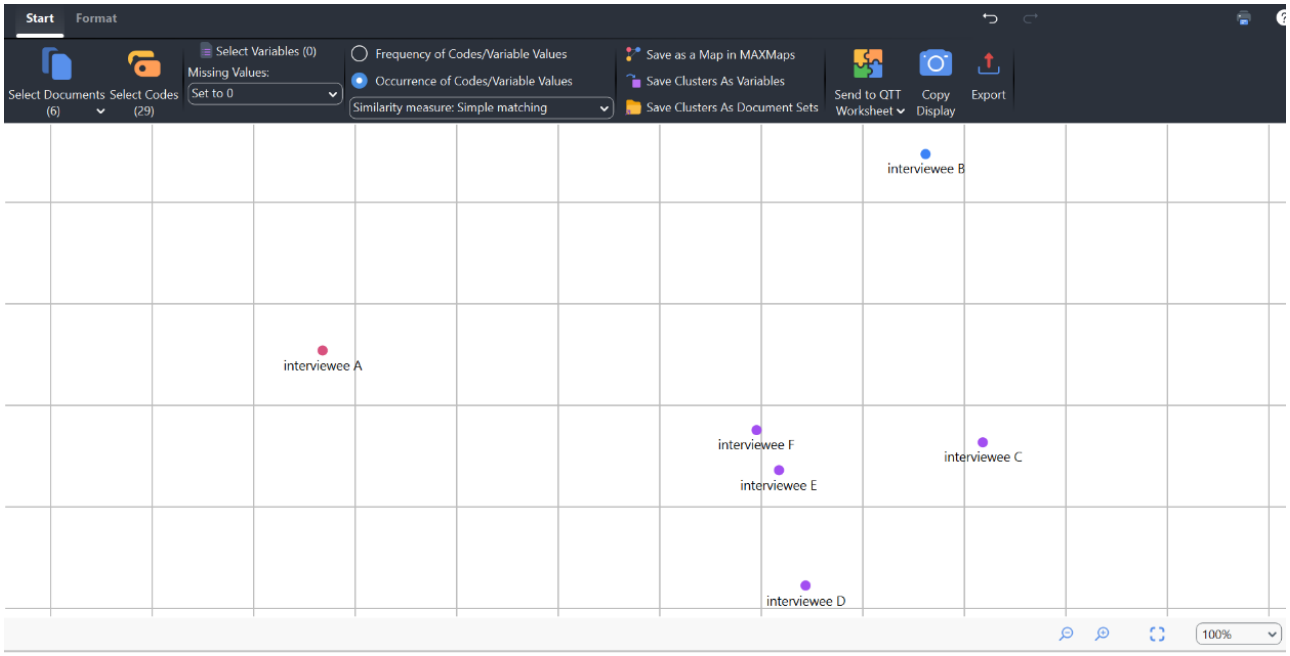

Figure 7. Document Map Visualization
Source: Compiled by the author using MAXQDA software

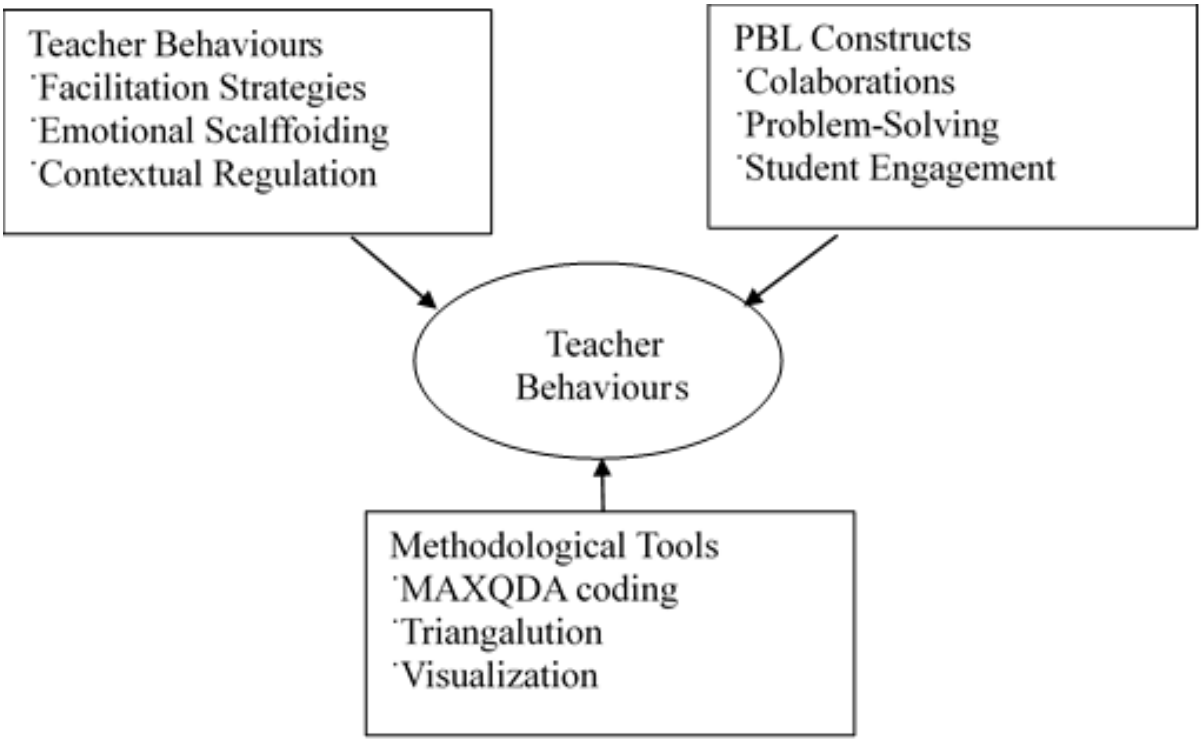

Figure 8. Conceptual Model of Teacher Behaviour in PBL
Source: Compiled by the author

This figure depicts the interconnections among teacher behaviours (i.e., facilitation strategies, emotional scaffolding, contextual regulation), central PBL constructs (i.e., collaboration, inquiry, adaptive practice, problem-solving, student engagement), and methodological tools (MAXQDA coding, triangulation, visualization) in the areas labelled 'integration zone' where they form, together, a model of teacher behaviour in a PBL theory-driven way.

4.7 PBL and Collaboration in Student group learning

In the pedagogical framework of Problem-Based Instruction, collaboration is not only a prime mover in the learning process but also a catalyst for knowledge building and social interaction. Thus, the essence of PBL is to motivate the student to investigate real problems collaboratively in a group setting, not only by investigating data and then inferring about what meaning could be made from the problem, but also how to hypothesize possible solutions, condense their thoughts about possible solutions into some coherent physical form, and reflect on them with their peers. All of these depend upon the extent, depth, and quality of the collaborative interactions that take place. The use of collaborative relationships in PBL may be considered from three dimensions:

4.7.1 Learner Collaboration among Peers

Students work together in small groups engaged in open-ended problem solving, which requires task allocation, the integration of perspectives, and agreed-upon decision making. The interactions that develop in these situations are aimed at promoting the social construction of knowledge and the application of higher order skills such as communication, critical thinking, and teamwork. Research shows that collaborative learning produces more motivation, more accountability, and the use of more perspectives.

4.7.2 Cooperation between Educators and Learners

In PBL, the teacher is less a deliverer of knowledge and more a facilitator of learning and designer of learning environments. He can clarify problems via questioning, timely feedback, and providing contextual scaffolding so that students can more deeply inquire and reflect on their learning events. The collaborative teacher/student work that results leads to a safer environment for learning and nurtures student control of their learning.

5. Issues of MAXQDA, PBL Implementation, and Student Collaborative Learning

5.1 The MAXQDA Software

5.1.1 Benefits of Using MAXQDA

MAXQDA is a powerful qualitative analysis tool that provides support for different data types such as text, images, and video. This leads researchers to be flexible in the application of various qualitative methodologies (Professor *et al.,* 2019). The mixed methods functionality of the software attends specifically to the combination of qualitative and quantitative data through either outcome-related strategies or data processing strategies (Kuckartz & Rädiker, 2022; Guetterman & James, 2023), thus contributing to the depth of the analysis. Furthermore, MAXQDA is relatively intuitive in its usability and user friendly, thus allowing researchers to undertake codes and categories efficiently, especially in respect of thematic analysis, and complex data-set planning.

5.1.2 Drawbacks in MAXQDA

Because the software is easy to use, beginner researchers can find that there is a lot to learn regarding the advanced sections, especially with respect to mixed methods analysis (Guetterman & James, 2023). There is also the impediment of the high cost of the software to be funded, as this may limit its availability in constrained research environments (Professor *et al.,* 2019). It should also be noted that excessive dependency on software tools may be detrimental to the development of core qualitative research skills such as critical reflection and interpretative insight (Sandhiya & Bhuvaneswari, 2024). Thus, while MAXQDA provides good technical support for qualitative research, researchers should exercise care in its use and be aware of the balance between the use of tools and conventional analytical skill development.

5.1.3 Methodological Constraints of MAXQDA

While MAXQDA provides robust support for qualitative analysis, several drawbacks deserve further attention. One is that the coding process is interpretive and requires the researcher's judgment. The risk is that the "coded"

teacher behaviours of students' interactions reflect the researcher's preconceptions more than those of the teacher. Findings may be inadvertently shaped in the researcher's image, for good or ill. Another is that the data are now represented as visualizations, such as code matrices, in MAXMaps. Patterns that seem clear visual interpretations can be paradoxically misleading, obscuring a contradiction within the raw transcripts. Yet another potential danger is that the partitioning, or segmenting, of the transcript undermines the teacher's flow. Teachers' habits or behaviour, their reflective commentary on what is happening, can only be understood in the context of the larger pattern of events occurring over extended time frames, yet are often coded separately.

5.2 Employing MAXQDA in PBL Teaching Research

As a mature qualitative data analysis software tool, MAXQDA demonstrates great potential in teaching research into Problem-Based Learning pedagogy. Researchers can benefit from using the coding and categorization functions to systematically process classroom recordings, interview transcripts, and student learning portfolios. This also in turn allows further analysis of linguistic traits and non-verbal behaviour, as well as decision-making processes within the collaborative student-teacher interactions. The integration of theory-driven and data-driven coding processes allows researchers to construct an empirically based Collaborative Learning Behaviour Model thus obtaining insights into the deeper structures of instructional interaction.

In research designs that integrate PBL, collaborative participation, and MAXQDA, the analytical focus may then be on how teachers design rich and challenging problems, how students demonstrate knowledge construction and problem-solving skills through collaborative interaction, and the ways in which teacher direction words and feedback strategies affect students' learning momentum and the quality of group cooperation. MAXQDA plays an important part in the process in this respect, not only by demonstrating the latent structures and behavioural patterns within such interactions, but also by providing good analytical support for both instructional practice and theoretical development too.

5.3 Application of Student Collaborative Learning

The instructional context of PBL is characterized by the dynamic, interactive collaboration of students and the tension of knowledge construction. It is the duty of teachers, therefore, to prepare not only some challenging and contextual problems, but also to promote the learning rate of students and the collaborative quality through an assortment of language and feedback strategies. It is just in this complex pedagogical interaction that qualitative analysis instruments, such as for example, MAXQDA manifest their effectiveness. Researchers can functionally utilize MAXQDA in the coding and comparison of classroom video recordings, the transcription of interviews, and the student artifacts in order to expose language features, nonverbal behaviours, and problem-solving strategies examined during collaborative interactions. Such an augmented global framework makes it possible to essentially build theoretical models of learning behaviour. Not only is this a good way to expose major behavioural patterns involved in PBL instruction, but it is an activity that provides the operational and evaluative route involved in educational research.

5.4 Cross-Cultural Reflections on Teacher Behaviour in PBL Contexts

This study first explored teacher behaviour in PBL with the aim of extending existing findings from international studies. Li and Tsai (2018) found a teacher evolving from a traditional didactic approach to adopting inquiry-based facilitation in Taiwan, which is consistent with Hmelo-Silver's (2004) findings about self-directed learners in Western PBL. Teacher agency and reflective practice were also features found in this study that run parallel to Biesta *et al.,* 2015, who focused on teacher agency in Europe. Agency is mapped here in our data extracted from East Asian PBL classrooms as part of teacher behaviour intended to be recognized and enacted in the local PBL classroom. Estaji and Fatalaki (2022) and Abrahama *et al.* (2025) presented qualitative work from Iranian and Indian studies of teacher development in relation to PBL. The use of MAXQDA for triangulated qualitative analysis was the mechanism for working with teachers/students and school culture, also adopted in those studies. We extended that work and conducted a replication study via MAXQDA to focus on behaviour - PCK - while also infusing teacher maps.

5.5 Limitations and Scope of Generalization

While this research generates significant evidence on teacher behaviour in the PBL context, there are limitations to be aware of:

5.5.1 Small sample

The data are drawn from purposively selected 6 interviewees from across 3 universities. While experienced in teaching PBL, the small sample size excludes a range of teacher views and contexts and will affect generalizability.

5.5.2 Need for data saturation / thematic saturation

While the authors explicitly sought thematic saturation through coding and triangulation, the lack of number of case studies limits how varied the teachers drawn by them from their sample can be. Larger, more varied samples may more clearly prescribe the variety of Teacher Behaviours."

5.5.3 Situational transferability

This study draws from higher education in Taiwan. Teacher contexts may differ in learning outcomes for a wide range of reasons.

5.6 Positionality and Reflexivity in Qualitative Inquiry

First, the researcher's professional background shaped the sensitivity to issues of facilitation, scaffolding, and contextual regulation from both teacher education and analytical knowledge in administrative law. Such background naturally empowered the researcher's ability to understand classroom interactions, but also held the risk of skewing interpretation in favor of certain pedagogical perspectives. Reflexive journaling enabled the identification of such biases and assumptions. Second, triangulation within the study (classroom transcripts, interviews, and other instructional documents) provided a form of counterbalancing subjective perspectives. For example, comparing teachers' accounts of their own gesturing with the gesturing themselves can reveal discrepancies in teachers' accounts with the data. Finally, ethics were a key to the researcher's role, including informed consent, transparency, and respect for the confidentiality of all participants, including teachers' professional identities. A stance assumed with humility recognizes that each of us sees things in the light of our particular cultural and institutional setting. As such, interpretations will not necessarily have the same currency in all worlds.

6. Conclusion

This study analyzed teacher behaviour in problem-based learning classrooms in relation to Pedagogical Content Knowledge, utilising MAXQDA for qualitative analysis of classroom transcripts, interviews, and instructional documents. The study identified three significant dimensions of practice for teachers engaged in PBL: facilitation strategies, emotional scaffolding, and contextual regulation. These behaviours signal how teachers adapt disciplinary knowledge into settings for collaborative learning, scaffold student engagement with effortless adaptation practices of collaboration, and demonstrate the emotional groundwork for teachers' own professional development. Regarding methodological implications, this study demonstrates how coding and triangulation in multiple data sources allow for greater attention to the transparency and rigor of analytic processes, while also elevating qualitative sources of evidence in teacher adaptation to learner-centered conditions.

This study also notes some methodological limitations. The small sample of six interviewees limits generalizability, and while thematic saturation was sought, this study doesn't claim a true share of the vast diversity of teacher behaviour across disciplines in PBL. This study is carried out in just one institutional setting within Taiwan's higher education context. The implications of study findings on teacher education programs, especially those that support teachers' collaboration and reflective practices. As the results were mostly generated from Taiwanese higher education with experienced PBL practitioners, more studies in other settings are needed to validate the findings of the research reported. This study acknowledges the current limitations and calls for similar studies with cross-national

comparisons and/or larger sample sizes to validate the research findings. Despite numerous limitations, this study aims to advance the ongoing discussion on the role of teacher behaviour in problem-based learning by linking a professional knowledge framework with qualitative inquiry methods and emphasizing reflectivity, procedural clarity, and transparency.

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Author Contribution Statement

The author confirms sole responsibility for the conception of the study, data collection, analysis, writing, read and agreed to the published version of the manuscript.

Does this article screen for similarity?

Yes

Conflict of Interest

The author has no conflicts of interest to declare. There is also no financial interest to report. The author certifies that the submission is original work and is not under review at any other publication.

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