

## Exploring Project-Based Learning in the SVVR Environment: An Epistemic Network Analysis of Pre-service EFL Teachers

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### Abstract

**Background:**

The goal is to explore how pre-service EFL teachers develop spherical video virtual reality (SVVR) projects, applying technological (TK), pedagogical (PK), and content knowledge (CK).

**Methodology:**

The data was collected from artifacts of pre-service EFL teachers' SVVR, and then analyzed using epistemic network analysis, a quantitative ethnography analysis.

**Findings:**


The pre-service EFL teachers primarily utilized TK features when designing virtual reality projects. These projects incorporated text-to-speech (TTS) to offer authentic speakers.

**Conclusion:**

This study showcased the extent to which pre-service EFL teachers developed their virtual reality projects and the features they used.

**Originality:**

Our study, utilizing epistemic network analysis, adds a layer to the common analysis, enriching the understanding of pre-service teachers' SVVR projects.

<b>Keywords</b>	:	epistemic network analysis; pre-service EFL teacher; project-based learning; SVVR; teacher education
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## 1. INTRODUCTION

Spherical video virtual reality (SVVR) offers interactivity and immersion, proving to be a strong tool in language learning. [Ebadi & Ebadijal \(2020\)](#) suggest that SVVR particularly enhances English as a Foreign Language (EFL) learning. Virtual reality provides 360-degree videos, allowing users to explore in any direction using handheld or standard computer devices ([Chen & Hwang, 2022](#)). Its user-friendly nature, regardless of computer skills, enables EFL teachers to develop immersive, interactive learning environments for second or foreign language students ([Chien et al., 2020](#)).

The idea of integrating SVVR into teacher education has been gaining traction due to its simple design potential. [Kozlova and Priven \(2015\)](#) explored how pre-service English as a Foreign Language (EFL) teachers used 3D virtual worlds to enhance engagement in lessons. However, despite the potential benefits, the technical and financial obstacles of using virtual reality can be daunting for teachers ([McFaul & Fitzgerald, 2019](#)). Even when the platform is readily available, many teachers may struggle to create virtual reality content without adequate instruction ([Lin & Wu, 2023](#)). In this context, SVVR could be a compelling solution. Unlike high-immersive virtual reality, which offers a 360-degree 3D virtual environment with a sense of physical presence, SVVR is a more affordable and flexible option. It can be used with or without goggles, on a standard computer or a mobile phone ([Jong et al., 2020](#)). This flexibility makes it particularly suitable for teaching students, fostering creativity and active engagement through easy-to-use devices.

Numerous studies (e.g., [Chen et al., 2021](#); [Hwang et al., 2024](#)) have explored the use of SVVR in EFL learning. However, there's minimal focus on pre-service teachers' abilities to design or create virtual reality during their training. Furthermore, integrating the SVVR design into the technological pedagogical framework could aid the use of emerging technologies, such as SVVR, in project-based learning (PBL) settings. This area could benefit from increased focus.

To craft an effective SVVR learning environment, pre-service EFL teachers need to merge instructional and content knowledge with technological know-how ([Liu & Kleinsasser, 2015](#); [Tseng & Yeh, 2019](#)). This aligns with the Technological Pedagogical Content Knowledge (TPACK) framework ([Koehler & Mishra, 2009](#)), which includes three core knowledge areas: technological knowledge (TK), pedagogical knowledge (PK), and content knowledge (CK).

As illustrated in Figure 1, TK extends beyond simple operation of various technologies. It's about choosing the right technologies and features for specific tasks. PK embraces understanding of learning theories, classroom management, lesson planning, and student evaluation. It empowers teachers to grasp how students build knowledge and to apply teaching practices that support learning. CK, on the other hand, refers to the subject matter, including learning concepts, theoretical frameworks, and summaries. Therefore, the TK, PK, and CK framework has been instrumental in enhancing pre-service EFL teachers' skills in technology integration (Lin & Wu, 2023; Tseng & Yeh, 2019).

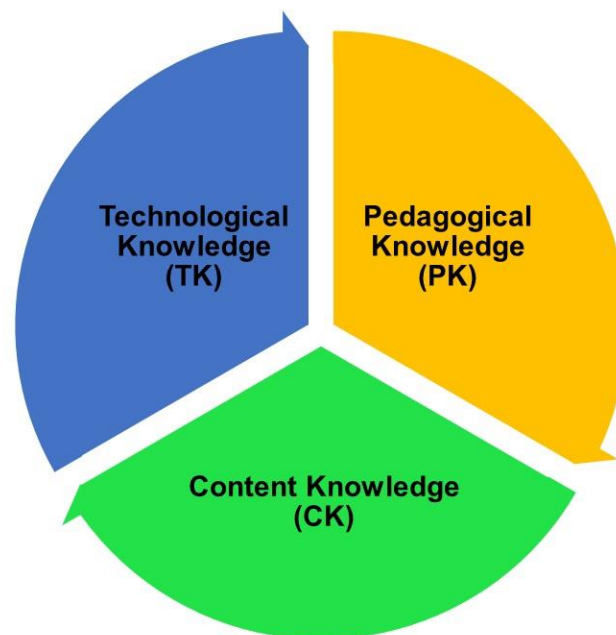


Figure 1 The framework of TK, PK, and CK

The PBL is in line with the constructivism learning approach (Vygostky, 1978), promoting teamwork to tackle problems. Krajcik and Blumenfeld (2006) pinpoint three core elements of PBL: generating driving questions, creating artifacts, and collaborating with peers.

First, generating driving questions involves students crafting questions that guide them in achieving meaningful project goals. An effective driving question is open-ended, feasible for students to address, and relevant, making it interesting. Bell & Mladenovic (2015) proposed that one technique to generate potent driving questions for teacher training is to involve pre-service teachers in class observations and stimulate critical reflection on teaching practice issues. Second, developing artifacts, or the SVVR environment in this study, is required to handle the issues brought up by driving questions. This process engages students in a range of activities such as planning and creating products, while exchanging ideas with their peers.

Finally, peer collaboration is crucial as knowledge is developed and co-constructed collectively, not individually (Wenger et al., 2002).

A handful of studies have explored the use of Problem-Based Learning (PBL) in training pre-service EFL teachers. Liu and Kleinsasser (2015), and Tseng and Yeh (2019) are notable examples that examined the competencies of pre-service EFL teachers in developing computer-assisted language learning for secondary and higher education. However, to the best of our knowledge, no recent studies have applied PBL to pre-service EFL teachers to create a SVVR learning environment within the Technological Knowledge, Pedagogical Knowledge, and Content Knowledge framework. More specifically, a detailed examination of students' design preferences and choices in developing an SVVR project, using learning analytics such as Epistemic Network Analysis (ENA), has not been conducted.

Shaffer (2017) introduced ENA as a key analytical method in quantitative ethnography. This method has shown its value in analyzing complex thoughts and behaviors via a generative process, as noted by Sun et al., (2022). In contrast with similar analyses such as content analysis, ENA takes the scientific learning theory a step further within the epistemic framework, moving past traditional static quantitative analysis (Shaffer, 2017). Gašević et al. (2019) suggested that ENA does not view knowledge and skills in a vacuum. Instead, it focuses on professional cognition and behavior in a complex field, where knowledge, skills, and their interconnections are key. In ENA, these elements are visualized as nodes in a network diagram, with lines between nodes illustrating their relationships (Shaffer, 2017). Therefore, ENA holds substantial potential for analyzing the association of competence components for pre-service EFL teachers. In this study, we used ENA to pinpoint competence differences among pre-service teachers designing SVVR projects, based on the fundamental TPACK theory framework.

Considering the gaps identified previously, this study puts forth the following research questions:

- (1) How do pre-service EFL teachers apply technological (TK), pedagogical (PK), and content knowledge (CK) when designing instruction in SVVR project-based learning environment?
- (2) What are the components of technological (TK), pedagogical (PK), and content knowledge (CK) that are most prominent used in pre-service EFL teachers during SVVR project-based learning activities?

## 2. METHODOLOGY

We conducted a study involving 14 pre-service EFL teachers in their first year of a Digital Learning course at a private university on Java Island, Indonesia. The group, consisting of twelve females and two males, had no prior experience in designing SVVR learning environments for students, nor had they participated in any courses focused on instructional design for virtual learning environments. All participants were taught by the same instructors. The SVVR project-based learning was integrated into the course curriculum, spanning five sessions each lasting 100 minutes per week.

During the first week, we introduced Uptale (<https://www.uptale.io/en/>), a web-based SVVR system that creates immersive, contextualized, and interactive learning environments. We opted for Uptale due to its cost-effectiveness and user-friendly interface, requiring minimal computer skills. Uptale provides users with the ability to incorporate 360° panoramic video or images, text descriptions, narratives, interactive questions, sounds, and voice recordings into each scene, among other features. To ensure all participating pre-service EFL teachers could fully utilize Uptale's features, we conducted a training workshop.

Moreover, we taught the participants how to incorporate technological, pedagogical, and content features into the system. In the second week, we paired the pre-service EFL teachers and tasked them with arranging scenes contextually within the SVVR learning environment. Their designs were based on pre-determined lesson plans, which included learning objectives, user levels, learning focus, timings, and activities. We also instructed them to use system editing features such as scene editing, tag editing, media management, and goal setting (see Figure 2). In the third and fourth weeks, each pair was tasked with designing a full lesson in the SVVR learning system. These projects were then presented in the fifth week.

Figure 3 showcases the SVVR learning environment used by the pre-service teachers. Examples of their SVVR projects include facilitating conversations between two students, incorporating educational videos, soliciting opinions, and conducting formative assessments.

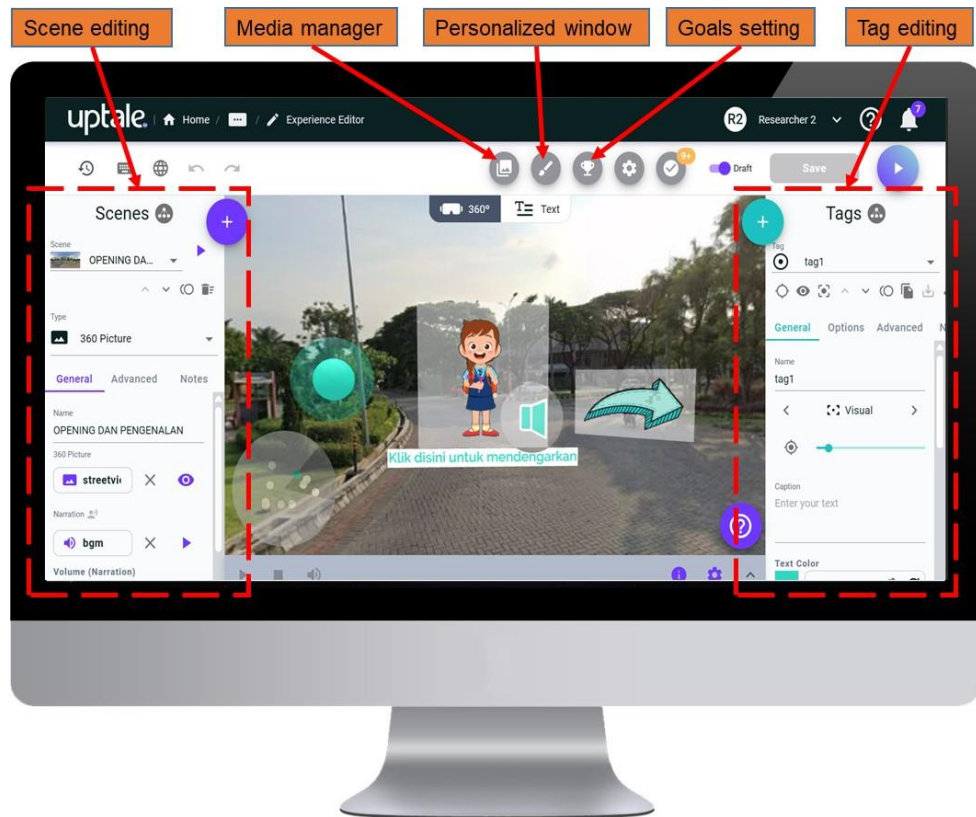


Figure 2 The SVVR design and editing system



Figure 3 sample of SVVR projects designed by pre-service EFL teachers.

In order to evaluate how pre-service EFL teachers implemented TK, PK, and CK in their SVVR projects, we utilized the Epistemic Network Analysis (ENA) as our analytical instrument (Shaffer, 2017). ENA enables scrutiny of the relational patterns between codes by creating network graphs derived from the weighted connections that emerge from code co-occurrences (Shaffer & Ruis, 2017). Our structured analysis procedure commenced with the

collection of students' artefacts and the development of a codebook based on these artefacts. Initially, we adopted a deductive coding approach grounded in the TK, PK, and CK of the TPACK framework model (Koehler & Mishra, 2009). Two independent coders coded all the lines in accordance with the prepared codebook, achieving a consensus ( $\alpha = 0.91$ ). The complete codebook is available in Table 1.

Table 1 The codebook of TK, PK, and CK for epistemic network analysis

Code parent	Code	Description
Technological knowledge	speaker	Speaker button shown
	back_music	Background music
	gamify	Gamification
	cam_image	Image button shown
	record	Recording button shown
	scene	Background scene
	video	Video button shown
	tts	Text-to-speech shown
	slide	Slides button shown
	quiz	Quiz model shown
Pedagogical knowledge	lead_in	Providing lead-in to introduce the topic
	reward	Giving a reward after step completion
	give_feedback	The system gives feedback on student's answers or viewpoints.
	aut_speaker	Authentic teacher voice was used in the virtual environment.
	learn_goal	The learning goal was stated in the virtual environment.
Content knowledge	learn_guide	Providing learning guides for students to explore the virtual environment
	formative	Providing formative assessment
	info_box	Information Box
	im_know	Image to lead the information or learning
	aut_info	Authentic information delivered by teacher's voice
	vid_know	Learning content video
	slide_know	Learning content slides
	summ	Learning summary or conclusion
	multi_choice	Multiple choices questions
open_ended	Open-ended questions or feedback	

Next, we used ENA Webkit (<http://www.epistemicnetwork.org/>) to analyze our data collection, consisting of 385 coding fragments from seven SVVR projects. We loaded this data into the ENA Webkit to examine the TK, PK, and CK aspects developed by each pair of pre-service EFL teachers.

For the first research question, we took the group as a unit and used the coding identification as a conversation and code parent (i.e., TK, PK, CK) to compare these three types of knowledge in the SVVR projects. We set the window stanza size to 4 to model the

connection lines within the three code parents. As for the second research question, we entered the codes from each code parent separately. This was to determine which TK, PK, and CK features were most frequently used and designed by each pair of pre-service EFL teachers.

### 3. FINDINGS

#### *3.1 How do pre-service EFL teachers apply technological (TK), pedagogical (PK), and content knowledge (CK) when designing instruction in SVVR project-based learning environment?*

As illustrated in Figure 4, the overall use of Technological, Pedagogical, and Content Knowledge (TK, PK, and CK respectively) in the SVVR projects is depicted on the left side of the figure in red. The mean scores of connection coefficients are represented on the lines. The red links indicate the combined strength of connections between the components for all pairs of pre-service EFL teachers. A connection coefficient of 0.64 between TK and CK signifies a moderately strong relationship. This indicates substantial integration of technology with content-specific knowledge in the design and implementation of SVVR projects in the aggregate data. The TK and PK connection, with a coefficient of 0.60, also reveals significant integration. This suggests effective linking of technological aspects to teaching methods. However, the PK and CK connection is the weakest, with a coefficient of 0.44. This suggests a weaker linkage between pedagogy and content knowledge compared to technology. It might indicate that pre-service teachers focus more on integrating technology with content and pedagogy, rather than connecting pedagogy and content independently of technology.

The comparisons between pairs (denoted in green) reveal three prominent connections; First, pairs 1, 2, and 3 demonstrate varying levels of connections. Pair 1 has a stronger PK to CK connection, signifying a focus on integrating pedagogical and content knowledge. Conversely, Pair 3 has a more pronounced TK to PK connection, emphasizing the integration of technology with pedagogical methods. Second, pairs 4 and 7 display the most pronounced TK to PK connections (0.82 and 0.77, respectively), suggesting an effective integration of technology with teaching methods. This could point to a strong focus on using VR technology in teaching methodologies. Last, pairs 5 and 6 take a more balanced approach, with no single connection taking precedence. This could be seen as a more holistic approach to integrating all three knowledge domains in the SVVR project design.

Each group's ENA profile illustrates their unique strategy for balancing Technological Knowledge (TK), Pedagogical Knowledge (PK), and Content Knowledge (CK). Some groups may rely more on technology integration, while others might strive for a more balanced mix of the three domains. The variations between pairs could stem from individual differences in understanding, experience, or focus during the project design phase.

In conclusion, the figure indicates a general trend towards integrating technology with both pedagogy and content in SVVR project-based learning. However, the extent of these



integrations varies among pairs. This variation can provide insights into where additional support or guidance may be beneficial for achieving a balanced integration of all three knowledge domains.

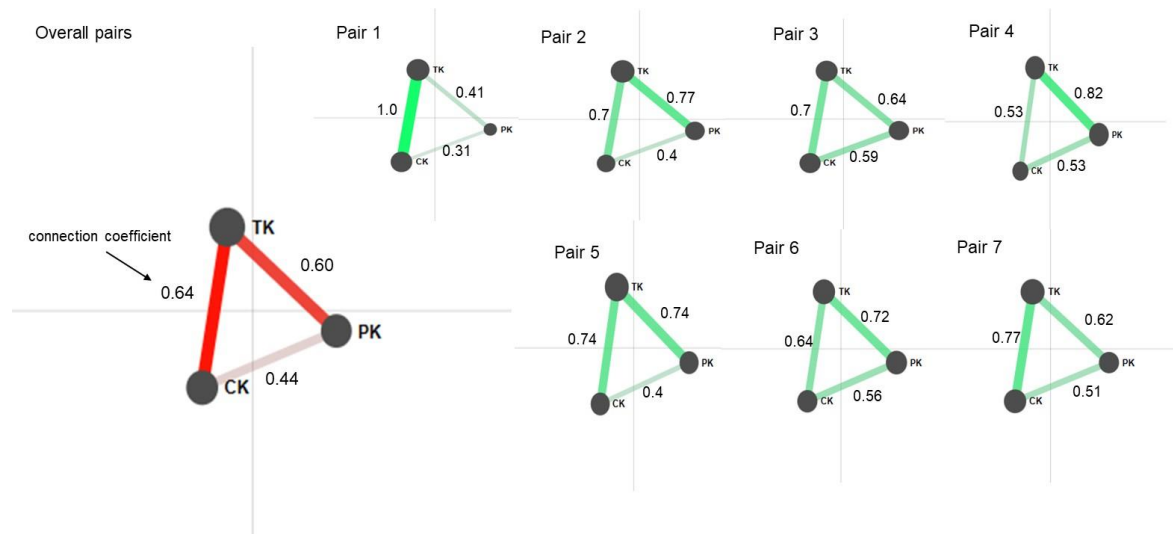


Figure 4 The overall application of TK, PK, and CK (red color) and each group (green color)

### 3.2 What are the components of technological (TK), pedagogical (PK), and content knowledge (CK) that are most prominent used in pre-service EFL teachers during SVVR project-based learning activities?

To better understand the differences in various features of technological, pedagogical, and content knowledge designed by pre-service EFL teachers, we used ENA for a detailed study of each knowledge type. The following sub-sections showcase the networks we constructed.

#### 3.2.1 Technological knowledge (TK)

Figure 5 illustrates that the most significant link is between "slide" and "video," with a relationship coefficient of 0.68. This indicates a strong emphasis on combining slide presentations with video, suggesting a multimedia approach to SVVR design. Pre-service EFL teachers appear to highly value the incorporation of visual aids with dynamic video content, a method particularly effective for language learning as it provides contextual cues and sensory engagement.

Other components like "tts" (text-to-speech), "scene," "record," and "cam\_image" cluster closer together, demonstrating moderate connections ranging from 0.26 to 0.37. These elements collectively hint towards an emphasis on creating interactive environments where spoken language is crucial. The use of text-to-speech technologies may indicate an effort to include automated speech to aid language learning, potentially for pronunciation, listening exercises, or interactive dialogues.

Interestingly, "gamify" and "speaker" are closely linked, but with a lower connection strength of 0.15 to "cam\_image." This suggests a potential integration of gamification and audio output with visual imagery, possibly to make the learning experience more engaging and interactive.

"Quiz" and "back\_music" stand as outliers with no direct links to the other elements. The position of "quiz" could indicate its consideration as an additional tool rather than an integrated part of the SVVR environment. The isolation of "back\_music" might suggest that it's not a primary feature of the designed SVVR experiences or that it's not effectively connected to other technological elements in the current design phase.

In conclusion, pre-service EFL teachers are actively applying their technological knowledge to create a rich, multimedia SVVR learning environment. The focus on combining slides and videos demonstrates an understanding of the value of multi-modal teaching aids in language learning. The connections between interactive elements like text-to-speech, recording, and camera imagery suggest a diverse approach to creating immersive content. The use of gamification indicates an innovative approach to maintain learner engagement. However, better integration of assessment tools (quizzes) and potentially music could create a more comprehensive and engaging learning atmosphere.

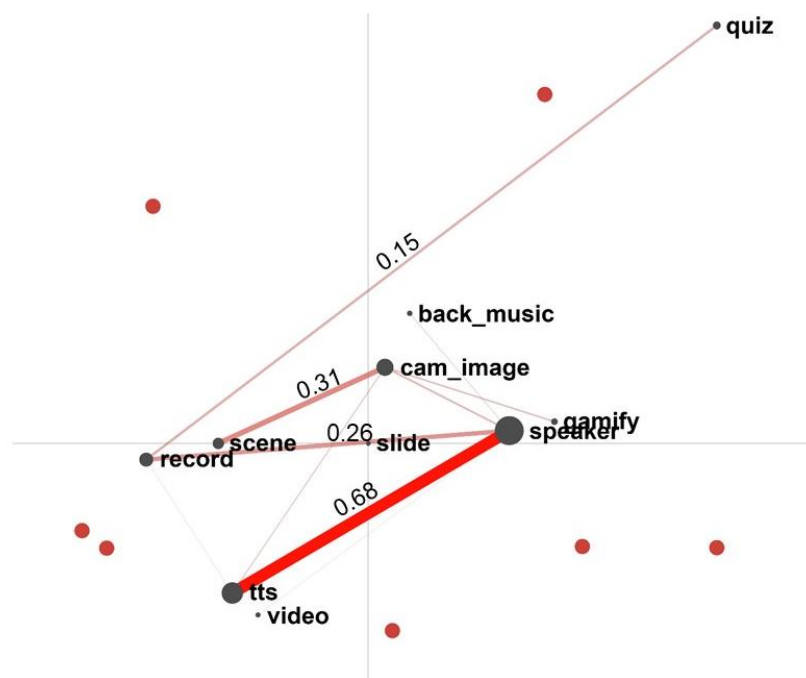


Figure 5 ENA network centroids of TK features in the SVVR projects

### 3.2.2 Pedagogical knowledge (PK)

Figure 6 clearly illustrates that the PK network mainly hinges on the integration of authentic teacher voice and learning guides, which enhances learner engagement and provides a scaffold for SVVR navigation. This integration, with a notable connection coefficient of 0.38, brings a human element into the virtual space, crucial for language acquisition. Simultaneously, the substantial link between system feedback and formative

assessments, with a coefficient of 0.24, emphasizes the importance of immediate, actionable feedback in reinforcing learning and guiding improvement.

However, the network also exposes weaker links, such as between clearly stated learning goals and the provision of learning guides, registering a lower coefficient of 0.13. This suggests a potential area for SVVR design enhancement, as explicit learning goals are paramount in providing clear direction and purpose to learners. Moreover, the pedagogical elements of rewards and topic introductions are underrepresented, which raises questions about their utilization within the SVVR. Enhancing the integration of these elements could elevate the learning experience and set the stage for meaningful learning encounters.

In short, while the pedagogical principles are well-applied in certain areas, addressing the identified gaps could significantly improve the SVVR pedagogical design. A holistic integration of pedagogical elements is necessary to optimize the effectiveness of SVVR in teacher education.

### **3.2.3 Content knowledge (CK)**

Figure 7 illustrates that the picture shows a strong link between "im\_know" (image leading the information) and "summ" (learning summary or conclusion), shown by a score of 0.73. This means the teaching heavily focuses on using images, which aligns with the idea of teaching using different methods. Visuals can quickly explain complex information and are especially helpful in EFL contexts where pictures can help understand language.

However, the picture shows a significant shortfall in the sound component, "aut\_info" (authentic information delivered by the teacher's voice). The weak links to "summ" (0.19) and "open\_ended" (0.13) suggest inconsistent ways of giving content, which might lessen the sound aspect of language learning. Authentic teacher talk is very important in EFL instruction because it exposes students to natural language patterns. This aspect should not be overlooked by visual elements in balanced teaching design.

Moreover, the placement of "info\_box" (information box), "vid\_know" (learning content video), and "slide\_know" (learning content slides) on the edges of the network indicates they are not used enough. These elements, usually central to CK delivery, could be better included to fully use the abilities of SVVR, creating a more immersive and engaging learning environment. The lack of a strong link to "multi\_choice" (multiple choice questions) in the visual representation suggests a missed chance to use interactive testing tools within the SVVR environment. Multiple-choice questions play a key role in checking student understanding and giving immediate feedback, both essential for adaptive learning. More strong inclusion of "open\_ended" questions could provide richer insights into the learner's understanding, fostering critical thinking and personalized feedback. However, the weak connection to "aut\_info" suggests a missed chance to synchronize content delivery with interactive feedback mechanisms.

In conclusion, while Figure 7 shows promising use of visuals in SVVR design, it also indicates a need for a more integrated CK framework that uses the full range of

teaching tools. Addressing these disparities could not only ensure balance between visual and auditory learning, but also strengthen the use of SVVR for comprehensive, interactive teacher education. Achieving coherence in the CK network requires a thoughtful combination of all elements, ensuring each component complements the others, thus providing a cohesive and enriching learning journey for students.

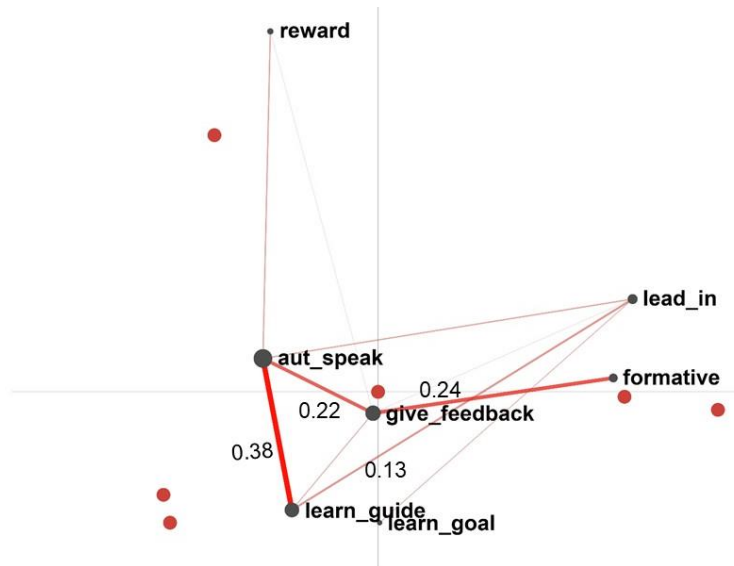


Figure 6 ENA network centroids of PK features in the SVVR projects

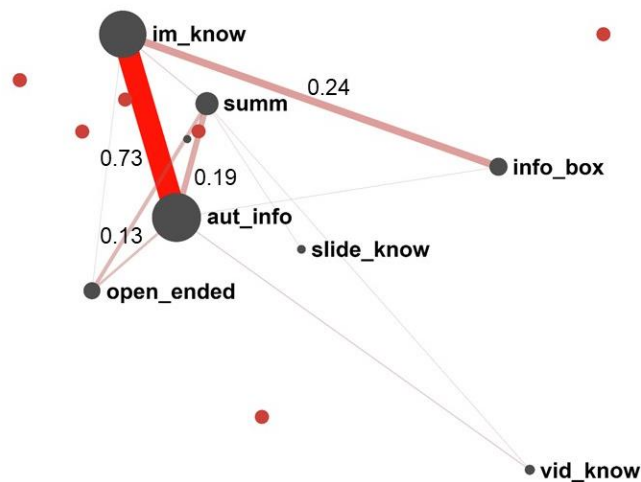


Figure 7 ENA network centroids of CK features in the SVVR projects

#### 4. DISCUSSION

This study aimed to explore how pre-service EFL teachers use TK, PK, and CK in designing a SVVR learning environment for project-based learning. The goal was to extend the application of the TPACK framework (Koehler & Mishra, 2009) in a PBL context, shedding light on the teachers' competencies in using TK, PK, and CK features for their SVVR project.

It was found that TK features were most frequently used by pre-service teachers in their SVVR designs, supporting their PK and CK features. However, the connection between PK and CK was less prominent. PK is the understanding of learning processes, while CK is the knowledge about the specific subject matter. The limited use of PK to support CK could be due to the teachers' focus on developing suitable SVVR content rather than incorporating a wide range of learning theories. This aligns with [Tseng and Yeh's \(2019\)](#) findings that students' artifacts reflected knowledge of specific theories used in their projects. Similarly, most pairs focused on using TK features to support PK and CK, without extending the learning theories that could be included as PK features.

Upon closer examination of the specific features of TK, PK, and CK in the SVVR projects, the most common feature was the integration of text-to-speech (TTS) into a speaker button. This is likely due to the SVVR platform's ability to translate text into any desired language and accent, which supports [Lin and Wu's \(2023\)](#) suggestion that Uptale is accessible even for students with beginner-level computer skills. In terms of PK features, authentic teacher feedback was frequently used. Previous studies have argued that providing an authentic environment for students can positively impact learning outcomes ([Hwang et al., 2022](#)). For CK features, images were often used to provide authentic information. Examples include maps, learning cycles, or images depicting causal relationships. These added elements help engage students in the SVVR learning environment by allowing them to click on each image for a deeper understanding of the content.

## 5. CONCLUSION

This study offers valuable insight into how EFL teacher education can utilize state-of-the-art tools like SVVR to boost pre-service teachers' skills in a PBL setting. The PBL approach incorporated SVVR environment observation, paired discussions, and collaborative design of an SVVR learning environment for students. The findings highlight the unique characteristics of each TK, PK, and CK in their SVVR designs, which could serve as a blueprint for creating more interactive digital learning tools for improved learning outcomes.

While this study sheds light on how pre-service EFL teachers developed their SVVR project, there are some limitations that warrant discussion for future SVVR and PBL-based research. Firstly, we did not examine or assess the pre-lesson plans designed by pre-service teachers to determine if their SVVR project was accurately reflected in or differed from these plans. Secondly, the limited time allocated for training workshops might have restricted the development of some advanced features during the design process. Lastly, the pairing for collaboration could have influenced individual performance evaluation as we didn't delve into their roles during collaboration. Therefore, a more comprehensive qualitative analysis, perhaps

through interviews, could help understand the co-constructed knowledge process among pre-service teachers.

Furthermore, this research expands upon existing literature by providing a more detailed exploration through an epistemic network analysis. This approach can benefit researchers and practitioners implementing SVVR project-based learning, by providing insights into the efforts and preferences of pre-service EFL teachers while designing SVVR learning environments.

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## 7. REFERENCES

- Bell, A., & Mladenovic, R. (2015). Situated learning, reflective practice and conceptual expansion: effective peer observation for tutor development. *Teaching in Higher Education*, 20(1), 24-36. <https://doi.org/10.1080/13562517.2014.945163>
- Chen, C. H., Hung, H. T., & Yeh, H. C. (2021). Virtual reality in problem-based learning contexts: Effects on the problem-solving performance, vocabulary acquisition and motivation of English language learners. *Journal of Computer Assisted Learning*, 37(3), 851-860. <https://doi.org/10.1111/jcal.12528>
- Chen, M. R. A., & Hwang, G. J. (2022). Effects of experiencing authentic contexts on English speaking performances, anxiety and motivation of EFL students with different cognitive styles. *Interactive Learning Environments*, 30(9), 1619-1639. <https://doi.org/10.1080/10494820.2020.1734626>
- Chien, S. Y., Hwang, G. J., & Jong, M. S. Y. (2020). Effects of peer assessment within the context of spherical video-based virtual reality on EFL students' English-Speaking performance and learning perceptions. *Computers & Education*, 146, 103751. <https://doi.org/10.1016/j.compedu.2019.103751>
- Ebadi, S., & Ebadijalal, M. (2022). The effect of Google Expeditions virtual reality on EFL learners' willingness to communicate and oral proficiency. *Computer Assisted Language Learning*, 35(8), 1975-2000. <https://doi.org/10.1080/09588221.2020.1854311>

- Gašević, D., Joksimović, S., Eagan, B. R., & Shaffer, D. W. (2019). SENS: Network analytics to combine social and cognitive perspectives of collaborative learning. *Computers in Human Behavior*, 92, 562-577. <https://doi.org/10.1016/j.chb.2018.07.003>
- Hwang, G. J., Chang, C. C., & Chien, S. Y. (2022). A motivational model-based virtual reality approach to prompting learners' sense of presence, learning achievements, and higher-order thinking in professional safety training. *British Journal of Educational Technology*, 53(5), 1343-1360. <https://doi.org/10.1111/bjet.13196>
- Hwang, G. J., Chen, Y. T., & Chien, S. Y. (2024). A concept map-based community of inquiry framework for virtual learning contexts to enhance students' earth science learning achievement and reflection tendency. *Education and Information Technologies*, 1-26. <https://doi.org/10.1007/s10639-024-12454-z>
- Jong, M. S. Y., Tsai, C. C., Xie, H., & Kwan-Kit Wong, F. (2020). Integrating interactive learner-immersed video-based virtual reality into learning and teaching of physical geography. *British Journal of Educational Technology*, 51(6), 2064-2079. <https://doi.org/10.1111/bjet.12947>
- Koehler, M., & Mishra, P. (2009). What is technological pedagogical content knowledge (TPACK)?. *Contemporary issues in technology and teacher education*, 9(1), 60-70.
- Kozlova, I., & Priven, D. (2015) ESL Teacher Training in 3D Virtual Worlds. *Language Learning & Technology*, 19(1), 83-101. Retrieved from <http://llt.msu.edu/issues/february2015/kozlovapriven.pdf>
- Krajcik, J. S., & Blumenfeld, P. (2006). Project-based learning. In R. K. Sawyer (Ed.), *The Cambridge Handbook of the Learning Sciences* (pp. 317–334). New York, NY: Cambridge University Press
- Lin, R. P., & Wu, W. C. V. (2023). Exploring Multiliteracy of Pre-Service Language Teachers through Spherical Video-Based Virtual Reality. *Educational Technology & Society*, 26(3), 101-114. <https://www.jstor.org/stable/48734324>
- Liu, M. H., & Kleinsasser, R. (2015). Exploring EFL teachers' CALL knowledge and competencies: In-service program perspectives. *Language Learning & Technology*, 19(1), 119–138.
- McFaul, H., & FitzGerald, E. (2020). A realist evaluation of student use of a virtual reality smartphone application in undergraduate legal education. *British Journal of Educational Technology*, 51(2), 572-589. <https://doi.org/10.1111/bjet.12850>
- Shaffer, D. W. (2017). *Quantitative ethnography*. Cathcart Press, WI

- Shaffer, D., & Ruis, A. (2017). Epistemic network analysis: A worked example of theory-based learning analytics. *Handbook of learning analytics*.
- Sun, M., Wang, M., Wegerif, R., & Peng, J. (2022). How do students generate ideas together in scientific creativity tasks through computer-based mind mapping?. *Computers & Education, 176*, 104359. <https://doi.org/10.1016/j.compedu.2021.104359>
- Tseng, S. S., & Yeh, H. C. (2019). Fostering EFL teachers' CALL competencies through project-based learning. *Journal of Educational Technology & Society, 22*(1), 94-105. <https://www.jstor.org/stable/26558831>
- Wenger, E., McDermott, R., & Snyder, W. M. (2002). Seven principles for cultivating communities of practice. *Cultivating Communities of Practice: a guide to managing knowledge, 4*, 1-19.
- Vygotsky, L. (1978). Interaction between learning and development. *Readings on the Development of Children, 23*(3), 34-41.