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Students' Perspectives on the Use of 3D Digital Models for Cultural Transmission in Foreign Language Teaching

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Abstract

This study explores the use of digital 3D models as a new multimedia teaching tool for culture transmission in foreign language education. Conducted with 59 teacher candidates (32 English, 27 German) aged 20–30, the study compared 3D models with traditional (audio) visual materials such as drawings, videos, and 360-degree videos. A historical building and a modern educational institution were presented using these materials during the 2024–2025 academic year in the Educational Technologies course. Data were collected through pre- and post-tests and in-class interviews, focusing on participants' demographics, prior experience with 3D models, and their views on their effectiveness. Results showed that most participants found digital 3D models more effective than other materials in conveying cultural content, despite some uncertainties regarding their use.

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Introduction

Three-dimensional (3D) modeling has evolved remarkably since the emergence of personal digital computers in the 1980s (Hughes et al., 2014), when the first digital rendering tools enabled objects to be represented with realistic spatial properties such as depth, geometry, and texture. Initially used in technical and industrial domains such as engineering, architecture, and design, 3D modeling has gradually expanded into education with advancements in computer graphics and visualization technologies. The development of accessible software—such as Blender 3D, Autodesk, Cinema 4D, and later Microsoft 3D Viewer—has democratized 3D content creation, allowing educators and learners to interact with digital objects in immersive ways. These developments have transformed static, two-

dimensional instructional materials into dynamic and interactive learning resources that can simulate real-world experiences in virtual environments.

Another category of teaching materials includes three-dimensional real objects (realia) or their physical models. Real objects or models made of wood, cardboard, plastic, or textiles have long been used in various educational contexts (Berwald, 1987). Today, technological progress allows for the use of digitally produced three-dimensional models of real objects—an approach that is the focus of this study. According to various sources (A23D, n.d.; Dinita, 2018; Hughes et al., 2014), a digital 3D model is defined as a computer-generated visual representation that captures all dimensions of a real-world object. It incorporates geometry, surface texture, and optical properties into a digital format and can be viewed from multiple angles in 360 degrees. Unlike traditional two-dimensional visuals—often mislabeled as three-dimensional—digital 3D models truly represent an object's structural and formal aspects, including its depth dimension.

Figure 1. Visual objects and dimensions[1]

As shown in Figure 1, two-dimensional (2D) visuals can only depict the horizontal and vertical dimensions of an object. In contrast, 2.5-dimensional (2.5D) visuals are essentially 2D images enhanced to create an illusion of depth through techniques such as shadowing, isometric camera angles, or the use of stereoscopic glasses. However, this perceived depth is purely illusory and does not represent the object's actual spatial characteristics (3D Horse, 2018). A digital 3D model, by definition, represents all structural and formal aspects of an object—including its horizontal, vertical, and depth dimensions—along with texture and content. Such models can be sourced from platforms like SketchFab, NASA 3D, CGTrader, and Autodesk, or created using specialized software such as Blender 3D, Autodesk, or Cinema 4D.

[1] The visual taken from 3D Services India: https://www.linkedin.com/pulse/revolutionize-your-marketing-25d-animation-game-changer

From a pedagogical perspective, previous research has shown that 3D models contribute positively to learning processes in various fields. Studies have demonstrated their effectiveness in enhancing spatial reasoning, motivation, and conceptual understanding (Barnea & Dori, 1996; Fiolhais & Trindade, 2001; Özcan, 2016; Teplá, et al., 2022). These results indicate that digital 3D models provide richer learning experiences compared to traditional 2D visuals, enabling learners to observe, explore, and interact with objects in a more realistic manner. As educational technologies continue to evolve, 3D digital models have become an essential component of modern learning environments, promoting engagement, comprehension, and long-term retention.

The Directorate General of Secondary Education (OGM) under the Ministry of National Education has already included 3D models in its official materials for subjects such as biology, geography, physics, and chemistry (OGM, n.d.). However, no 3D materials have been designed specifically for foreign language education. Existing literature shows that most studies on 3D models are conducted in the context of 3D printing, digital games, augmented reality (AR), or virtual reality (VR) (Karagülle, 2020). The integration of 3D models into educational contexts was once limited to specialized fields like industrial design, film, and gaming. Until the release of Microsoft's 3D Viewer in 2015, the use of 3D models in education required advanced tools and skills. Since then, these models have become more accessible through web-based viewers that do not require additional software. Despite this increased accessibility, scientific studies examining the use of 3D models as standalone materials in education remain limited. Most focus on sciences such as physics, chemistry, biology, and geography, while research in language education is almost nonexistent.

The only academic study directly addressing the use of 3D models in foreign language instruction was conducted by Iinuma and Chiyokura (2008). They developed a digital 3D model of a historical building and implemented it in a 13-week vocational English course at Keio University. The findings indicated that students were highly motivated, enjoyed using the models, and improved their English reading, listening, and speaking skills. Notably, the 3D model was found to be more effective than traditional film materials. Nevertheless, similar empirical studies in other languages are still lacking, revealing a gap in the literature.

Language and culture are intrinsically linked, and cultural transmission is a core component of foreign language education (Council of Europe, 2001). Almost all teaching

materials, including textbooks, aim to convey both linguistic and cultural content. In this regard, 3D digital models hold significant potential for facilitating cultural learning by enabling learners to virtually experience authentic cultural objects, spaces, and monuments. However, they remain underutilized in language classrooms. To make effective use of such models, teachers must first be aware of their existence, understand their pedagogical value, and have access to them for instructional purposes. As Alyaz and Akyıldız (2018) have pointed out, many digital tools—such as educational games—are still underused in language instruction, reflecting an untapped potential for integrating technology into more engaging and effective learning environments.

Another frequently used material in language education is film, a medium dating back to the late 19th century. Films are often produced alongside textbooks and other resources by publishers specializing in foreign language instruction. Since 2005, platforms like YouTube, Vimeo, Dailymotion, and Bing have provided institutional or user-generated content for language learning. Numerous studies have explored the use of educational films, cinema, advertisements, and similar materials, particularly for cultural education (Maden & Kaya, 2023). A further development in audiovisual materials is the 360° video—also known as immersive, panoramic, or spherical video. Research has shown that 360° videos can enhance linguistic and cultural learning (Repetto et al., 2021), although the field remains in its infancy, with few empirical studies (Schroeder, et al., 2023). Presentations are another widely used material in language education, and studies have reported their positive impact on language skill development (Darancık, 2013; Kiss, 2016).

In this context, the present study explores the use of three-dimensional (3D) digital models produced in virtual environments as teaching materials for cultural content transmission in foreign language learning and compares them with other (audio)visual teaching materials. The Brandenburg Gate in Berlin and a school building were selected as cultural examples, and five different materials—images, presentations, videos, 360-degree videos, and digital 3D models—were used to introduce these landmarks.

Accordingly, the general purpose of this study is to investigate the effectiveness and pedagogical potential of digital 3D models as tools for cultural transmission in foreign language teaching. To achieve this purpose, the study addresses the following specific objectives:

1. To determine teacher candidates' familiarity with the concept of 3D models;

2. To identify whether participants have encountered 3D models during their own foreign language learning or teaching experiences;
3. To explore participants' views on the use of 3D models in lessons;
4. To evaluate the effectiveness of 3D models compared to other visual materials; and
5. To identify the perceived barriers to the widespread use of 3D models in language teaching.

By addressing these objectives, the study aims to contribute to the field of computer-assisted language learning (CALL) by raising awareness of the educational value of digital 3D technologies and encouraging their thoughtful integration into foreign language instruction.

Method

Research Design

This study employed a quasi-experimental and explanatory research design that did not include a control group, focusing instead on measuring changes within a single group of participants over time. By combining elements of both quantitative and qualitative research, the study aimed to provide a more comprehensive understanding of the effects of the instructional intervention. A pre-test–post-test approach was implemented to evaluate the impact of the intervention, allowing the researchers to observe changes in knowledge, attitudes, and intentions resulting from the use of digital 3D models in an educational context.

This mixed approach was chosen because it enables not only the measurement of statistically significant differences before and after the instructional activities but also the exploration of participants' subjective experiences and reflections. The quantitative dimension provided objective data on the degree of change in participants' perceptions, while the qualitative data offered deeper insights into how and why these changes occurred. Moreover, the quasi-experimental model was suitable for the natural classroom setting of this study, where random assignment to groups was not feasible. Through this design, the study sought to capture the pedagogical value of 3D digital models within authentic learning environments and to generate empirical evidence that could inform future applications of emerging technologies in foreign language education.

Study Group

The study group comprised 59 teacher candidates (46 female, 13 male) enrolled in an Educational Technologies course during the Spring and Summer semesters of the 2024–2025 academic year. Of these participants, 32 were studying English language teaching and 27 German language teaching. Participants' ages ranged from 20 to 30 years (M = 21.54). In terms of academic standing, 57.6% (n = 34) were in their second year, 23.7% (n = 14) in their third year, and 18.6% (n = 11) in their fourth year of undergraduate study. Regarding foreign language proficiency, 44% (n = 26) of respondents self-identified as A1–A2, 41% (n = 24) as B1–B2, and 15% (n = 9) as C1.

Data Collection and Analysis

Data were collected through instruments designed to obtain demographic information, measure participants' prior experiences with digital 3D models, and explore their perspectives on the use of such models in language education. Both quantitative and qualitative data collection tools were employed to ensure a comprehensive understanding of the research topic. The demographic information form gathered data on participants' age, gender, field of study, year of education, language proficiency level, and previous familiarity with digital 3D models. This form was reviewed by three experts in educational technology, foreign language education, and measurement and evaluation to ensure clarity and content validity. Since it served only a descriptive function, no statistical reliability analysis was applied.

Quantitative data were obtained using a 24-item survey that included both Likert-scale and open-ended questions. In the survey instrument, participants' opinions were measured using a five-point Likert-type scale, where 1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, and 5 = Strongly Agree. Accordingly, mean values between 1.00–2.49 were interpreted as low, 2.50–3.49 as moderate, 3.50–4.49 as high, and 4.50–5.00 as very high levels of agreement. The instrument was adapted from previous studies (Iinuma & Chiyokura, 2008; Özcan, 2016; Teplá, et al., 2022) and finalized following expert review to ensure content and construct validity. The survey measured participants' knowledge, attitudes, and intentions related to the use of 3D models in education. To determine internal consistency, Cronbach's alpha was calculated, yielding a coefficient of α = .725, which indicates an acceptable level of reliability for research purposes.

Qualitative data were collected through open-ended survey responses and semi-structured, face-to-face interviews conducted during class sessions. The original responses, which were provided in Turkish, were carefully translated into English by the researchers to ensure accuracy and preserve the intent and nuances of the participants' statements. These aimed to capture in-depth insights into participants' perceptions of the pedagogical benefits, challenges, and practical applicability of 3D digital models in language instruction. To enhance credibility, data triangulation was applied by comparing written and verbal responses, and two independent researchers coded the qualitative data. The intercoder agreement rate was 87%, demonstrating a high level of reliability. Data were gathered both online, via Google Forms, and in person before and after the instructional sessions. The pre-test was administered to determine participants' initial familiarity with and opinions about 3D models, while the post-test was conducted after the intervention to identify possible changes in perception. During the post-test phase, classroom interviews were held to obtain richer qualitative feedback. All participants were informed about the aims of the study, and informed consent was obtained prior to participation. Ethical principles such as confidentiality, anonymity, and voluntary participation were fully observed throughout the process.

Quantitative data were analyzed using the SPSS software package. Before performing statistical analyses, the dataset was examined for missing values and outliers to ensure completeness and accuracy. Because the pre-test and post-test scores did not meet the assumptions of normality, the Wilcoxon Signed Rank Test was applied as a non-parametric method suitable for paired, ordinal data. The results of this analysis were used to compare participants' responses before and after the instructional intervention. Qualitative data were analyzed thematically. Thematic analysis involved identifying and grouping recurring ideas and expressions into broader themes that reflected participants' perceptions and experiences. The qualitative findings were used to complement and enrich the quantitative results, providing a more holistic understanding of participants' views on the educational potential of 3D digital models in foreign language teaching.

Materials and Course Activities

The Brandenburg Gate in Berlin and a school building were selected as cultural examples, and five different materials—images, presentations, videos, 360-degree videos, and digital 3D models—were used to introduce these landmarks. Participants were then

asked to compare the materials. It is well known that various audiovisual materials, such as texts, drawings, photographs, videos, and presentations, have long been used in foreign language education. These materials have evolved alongside technological advancements, progressing from basic analog formats—such as text, visuals, and audio—to interactive texts (hypertexts), interactive visuals, videos, and presentations. These have become standard components in foreign language classes and instructional packages to varying degrees.

These landmarks were chosen to provide learners with culturally meaningful and visually rich content suitable for foreign language education. To present these cultural sites, five distinct types of instructional materials were used: static visuals (e.g., photographs and illustrations), presentations (e.g., PowerPoint slides), 2D videos, 360° panoramic videos, and interactive 3D models. While the majority of the static visuals, slide presentations, and introductory videos were sourced from publicly available online platforms, the presentations and 3D models used during the sessions (see Figure 2) were specifically created and customized by the researchers to align with the learning objectives. The instructional activities were delivered over the course of two weeks, with a total duration of four class hours. In addition to the presentation of materials, the sessions also included practical instruction on how to locate freely accessible 3D teaching resources and a hands-on demonstration illustrating how such models can be created and effectively integrated into foreign language teaching practices. This approach aimed not only to expose students to innovative educational tools but also to foster their digital literacy and pedagogical readiness for using 3D models in their own classrooms.

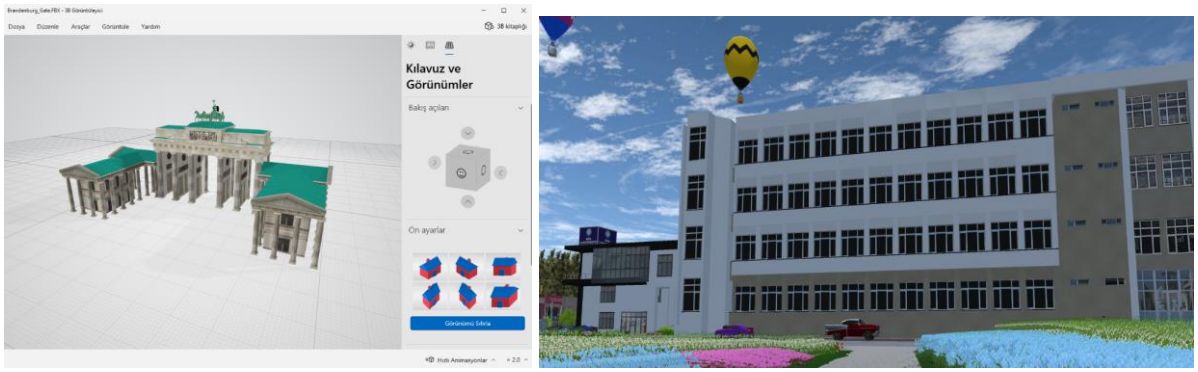

Figure 2. 3D models used in the lessons

The 3D models illustrated in Figure 2 (presented here as 2D cross-sections) enable detailed examination of all surfaces through 360-degree rotation along both horizontal and vertical axes, using software such as Microsoft 3D Viewer and the Unity Game Engine. These

models are also fully compatible with Microsoft Office applications, allowing for flexible use across various instructional platforms. As the development process of these instructional 3D models has been thoroughly documented in a previous publication (Alyaz, Spaniel-Weise, & Werner, 2018), it is not repeated in the present study.

Findings

The findings presented below address the study's research questions by outlining both statistical results and relevant participant insights. Participant-reported data on digital materials and applications previously used in foreign language instruction are summarized in Table 1.

Table 1. Digital materials used throughout the foreign language education process of the participants

Digital materials utilized in the foreign language learning process		**%**
Visuals (drawings, photos, posters, maps, etc.)	9	100
Online Computer-Assisted Applications (Web)	6	77.9
Applications for portable devices (Tablet/Phone)	4	74.6
Presentations (e.g. PowerPoint)	0	67.8
Offline Computer-Assisted Applications (CDs, DVDs, etc.)	3	55.9
Other visual materials	2	37.2
Educational digital games (PC, mobile, console, etc.)	9	32.2
Augmented reality applications		1.7
360-Degree (3D) films		1.7
Virtual reality applications		3.4
Digital 3D models		**0**

Table 1 shows that participants' foreign language learning experiences predominantly involved traditional visuals (100%). These results suggest that while learners are accustomed to standard digital learning environments, their exposure to immersive and interactive technologies remains extremely limited. The complete absence of 3D model usage highlights a significant gap in technological integration within foreign language education. This lack of familiarity may stem from limited awareness among educators, insufficient availability of subject-specific 3D content, and the technical challenges associated with developing or implementing such materials. Overall, the data point to an urgent need to expand the range

of digital tools used in language instruction by incorporating more innovative technologies—such as digital 3D models—that can enhance engagement, realism, and cultural understanding.

Paired-Samples t-Test results for this data are presented in Table 2.

Table 2. Pre- and post-test results of participants' opinions on using 3D models as teaching materials

Measurement			D	f	t	
3D models should be used in foreign language lessons.	pre-test	9	.6 87	8	3.45	-.001
	post-test		.9 75			
I can use 3D models in my future teaching.	pre-test		.4 92	8	2.87	-.006
	post-test		.8 81			

As seen in Table 2, the mean pre-test score (M = 3.4) regarding the use of 3D models in the foreign language learning process represents a moderate level of agreement, while the post-test mean (M = 3.9) corresponds to a high level. Similarly, participants' mean pre-test score for the statement on using 3D models in their future teaching (M = 3.6) increased slightly to M = 3.8 in the post-test, also reflecting a shift from moderate to high agreement. The statistically significant difference between pre-test and post-test scores ($p < .05$) indicates that the instructional activities positively influenced participants' attitudes toward using 3D models as teaching materials. However, as both post-test means remained below 4.00, the results suggest that participants' overall attitudes were positive but not yet strong, implying a degree of uncertainty or cautious optimism about applying 3D models in their own teaching practice.

Participants were asked to compare various media formats—namely photos, traditional films, 360° video materials, and interactive 3D models—with regard to their effectiveness in conveying cultural content. These materials were selected to represent a range of sensory and immersive experiences, allowing participants to reflect on how each format supports the understanding and transmission of cultural knowledge in foreign language education. The responses provided insights into participants' perceptions of engagement, realism, and educational value associated with each medium. The findings obtained from the analysis of these responses are summarized and presented in Table 3,

offering a comparative overview of the perceived strengths and limitations of each format in the context of cultural learning.

Table 3. Pre-test and post-test results comparing 3D models with other course materials

Measurement			D	f	t	
3D models are more effective than visual materials (photos, drawings)	pre-test	.8	88		-3.73	000
	post-test	.4	70			
3D models are more effective than film materials.	pre-test	.2	85		-3.05	003
	post-test	.7	83			
3D models are more effective than 360° video materials.	pre-test	3	78		-2.72	008
	post-test	.7	91			
3D models are more effective than presentations (e.g., PowerPoint).	pre-test	.8	88		-4.36	000
	post-test	.3	73			
Overall mean of all items	pre-test	.5	49		-5.45	000
	post-test	.0	56			

9 8

According to the findings in Table 3, the pre-test mean score (M=3.8) of participants who positively thought that 3D models are more efficient than traditional visual materials increased in the post-test (M=4.4). There is a significant difference between the pre-test and post-test mean scores ($p < .05$), indicating that participants consider that 3D models are more efficient than traditional 2D visuals. The mean score of participants who thought 3D models were more efficient than films also increased from the pre-test (M=3.2) to the post-test (M=3.7), with a significant difference between the pre-test and post-test. These findings show that the participants' moderately positive view that 3D models are more efficient than film materials increased to some extent; however, both the pre-test and post-test means were

lower than the mean scores for the efficiency of traditional visual materials. The mean score of participants who positively thought that 3D models were more efficient than 360° film materials increased from the pre-test (M=3.3) to the post-test (M=3.8), showing a significant difference ($p < .05$). These findings can be interpreted as participants considering that 3D models are more efficient than 360° films. The mean score of participants who thought 3D models were more efficient than presentation materials increased from the pre-test (M=3.8) to the post-test (M=4.3), similar to the increase in scores for visual materials, with a significant difference between the pre-test and post-test, indicating that participants believe 3D models are more efficient than presentation materials. The post-test mean scores show that participants consider 3D models are more efficient than all other materials. The overall mean score for all materials compared to 3D models increased from the pre-test (M=3.5) to the post-test (M=4.0), with a significant difference. The post-test findings show that participants evaluated 3D models as more efficient than traditional visuals (M=4.4), presentations (M=4.3), films and 360° films (M=3.7). The post-test mean scores being above 4, corresponding to 'Agree,' indicates that participants believe 3D models are more efficient than 2D visuals and presentation materials. Although the mean scores for comparing 3D models with films and 360° films were above 3, corresponding to 'Neutral,' these scores were quite lower than the mean scores for the efficiency of 3D models compared to 2D visuals and presentations. These findings suggest that while participants have a clear view that 3D models are more efficient than 2D visuals and presentations, their view is less clear regarding the efficiency of 3D models compared to film materials.

Possible reasons for the non-use of digital 3D models in foreign language courses were also asked to the participants. The ratios of the answers given by the 13 participants who responded to this question are presented in Table 4.

Table 4. Reasons for the limited use of 3D models in foreign language lessons

Reasons for limited use of 3D models in language learning	**N**	**%**
Difficulty in producing 3D models	46	77.9
Limited awareness of 3D technology in education	43	72.8
Insufficient 3D materials available for foreign language learning	32	54.2
Difficulty in integrating 3D models into lessons	13	22.0
Perceived uselessness of 3D models in lessons	2	3.3

As shown in Table 4, the main factors cited by participants for the limited use of 3D models in foreign language lessons include instructors' lack of awareness of the material (72.8%) and the difficulty in producing 3D models (77.9%). Other factors mentioned include the scarcity of 3D materials in the market (54.2%), the challenge of integrating them into lessons (22.0%), and the perception that 3D models are unnecessary in lessons (3.3%).

Some participants also shared additional thoughts on the use of 3D learning objects in foreign language education that were not covered in the survey. A number of these reflections highlighted both the potential benefits and the practical challenges of integrating such materials into classroom practice. Their statements reflected an awareness of the motivational, cultural, and technological dimensions of 3D learning tools, offering valuable insights into how preservice teachers perceive innovation in language education. Several participants emphasized the engaging and immersive qualities of 3D models, noting that these tools can increase students' interest and attention, particularly when cultural content is presented in a visually realistic way. Others pointed out that despite their potential advantages, 3D learning objects are still not widely used because teachers often lack the necessary training and resources to integrate them effectively. Concerns such as the cost of development, limited availability of language-specific content, and the time required for lesson preparation were also mentioned as significant barriers. Overall, the reflections indicate a mix of enthusiasm and caution: while participants acknowledge the transformative potential of 3D technologies in enhancing learner engagement and cultural understanding, they also recognize the practical constraints that must be addressed before such tools can become a routine part of language instruction. Selected participant opinions are presented below to illustrate these perspectives. For clarity, "P" refers to "preservice teacher."

> *"The integration of 3D objects into instruction increases student engagement and motivation, particularly as digital technologies become more embedded in daily life."* (P4)
> *"There is a lack of 3D models specifically designed for teaching the German language."* (P8)
> *"Teachers need training on how to use 3D models effectively; otherwise, their adoption will remain limited."* (P12)
> *"3D models are especially beneficial for conveying cultural elements in foreign language teaching."* (P3)
> *"It will take time for 3D materials to become as common as traditional visual aids; teachers should be informed and supported in this process."* (P9)
> *"The compatibility of 3D models with Microsoft applications facilitates their use, but a wider range of models is needed."* (P2)

> *"These materials may be particularly helpful for illustrating concrete concepts, but their overall impact on language learning could be limited."* (P6)
> *"Issues such as cost, age-appropriateness, and time requirements must be considered when using 3D learning objects."* (P7)

The original responses, which were provided in Turkish, were carefully translated into English by the researchers to ensure accuracy and preserve the intent and nuances of the participants' statements. Overall, the feedback centers on key themes such as target audiences, accessibility, teacher readiness, and financial considerations. Participants highlighted both opportunities and challenges associated with the use of 3D materials in language education. Many of the comments reflect not only practical concerns—such as the availability of technological infrastructure, the need for teacher training, and the affordability of the tools—but also thoughtful suggestions aimed at improving the effectiveness and feasibility of integrating 3D content into foreign language instruction. This feedback provides valuable insights into the conditions necessary for successful implementation and points to areas where further support or development may be required.

Discussion, Conclusion and Recommendations

This study investigated the use of digital 3D models in foreign language instruction, addressing five research questions through data collected from both quantitative and qualitative sources.

The findings of the first research question, *"Are teacher candidates familiar with the concept of 3D models?"*, show that most participants were unfamiliar with digital 3D models as instructional tools. Their limited awareness was largely confined to entertainment contexts such as gaming or virtual reality environments. This finding aligns with earlier observations that 3D technologies, although widespread in design, science, and media industries, are still emerging in educational contexts (Hughes et al., 2014). Similar to the current results, Iinuma and Chiyokura (2008) noted that students' first encounters with 3D digital objects often occur in non-academic settings, which limits their understanding of the technology's pedagogical potential. The lack of exposure identified in this study confirms that 3D modeling is not yet part of mainstream teacher education programs, leaving preservice teachers unaware of its relevance for foreign language instruction.

With respect to the second research question, *"Have participants encountered 3D models during their own foreign language learning or teaching experiences?"*, none of the participants

reported prior use of such materials. This outcome mirrors the current state of the literature, which shows that while 3D modeling has been applied in disciplines such as physics (Fiolhais & Trindade, 2001), chemistry (Barnea & Dori, 1996), and medical education (Özcan, 2016), its adoption in language learning remains minimal. The only known study in this field—conducted by Iinuma and Chiyokura (2008)—used 3D models in vocational English instruction and found positive results, yet the approach did not expand into broader language education contexts. The present study thus reinforces the view that 3D models, though technologically accessible since Microsoft introduced 3D Viewer in 2015, have not yet achieved curricular integration in language teaching. This lack of application underscores a significant research and practice gap in computer-assisted language learning (CALL).

Regarding the third research question, *"What are participants' views on the use of 3D models in lessons?"*, the results revealed generally positive but cautious attitudes. Participants expressed interest in using 3D models in their future teaching, though they remained uncertain about practical implementation. This cautious optimism supports previous findings that teachers' willingness to adopt educational technologies depends strongly on perceived usefulness and confidence in using digital tools (Ilter, 2009). Moreover, Alyaz and Akyıldız (2018) similarly noted that teachers recognize the motivational potential of digital applications but often refrain from using them due to limited pedagogical or technical preparation. The current study extends this understanding to 3D models, suggesting that successful integration requires structured professional training and ongoing institutional support.

The fourth research question, *"How do participants evaluate the effectiveness of 3D models compared to other visual materials?"*, produced favorable results. Participants perceived 3D models as more effective than conventional visual aids such as photos and PowerPoint presentations, and somewhat more beneficial than films or 360° videos. This finding is consistent with previous research indicating that three-dimensional and immersive media can enhance engagement and comprehension by providing spatial and experiential depth (Teplá, et al., 2022). Akyıldız (2025) likewise demonstrated that virtual reality technologies improve learners' motivation and cognitive efficiency in vocabulary instruction, supporting the view that interactive and realistic representations stimulate deeper learning. Although direct comparisons between 3D models and other media remain scarce, the convergence of evidence from adjacent technologies—such as VR and 360° video (Repetto et al., 2021)—

suggests that 3D models hold similar potential for improving cultural and linguistic engagement in foreign language classrooms.

Finally, the fifth research question, *"What are the perceived barriers to the widespread use of 3D models in teaching?"*, revealed challenges including lack of awareness, insufficient resources, and the technical complexity of model production and classroom integration. These obstacles align with prior findings that teachers often hesitate to adopt advanced digital tools due to limited training, infrastructure, and localized content (Karagülle, 2020). Similar barriers have been identified in the implementation of VR and AR applications, which also require high technical competence and hardware availability (Schroeder, Siegle & Craig, 2023). However, for some of the identified barriers—particularly those concerning teacher readiness and the availability of language-specific 3D materials—no direct research evidence could be found, highlighting the novelty of this area. Therefore, the present study not only confirms challenges known from related technologies but also identifies new ones specific to the integration of 3D models in language education, offering an agenda for future applied research.

This study represents one of the first efforts to explore the potential of digital 3D models in foreign language education. However, due to limitations in time, scope, and sample size, the findings should be interpreted with caution and are not generalizable beyond the current participant group. Nevertheless, the results indicate that teacher candidates recognize the value of 3D models, particularly for enhancing cultural transmission within language instruction.

Given the early stage of 3D model integration in educational contexts, further research is needed to assess their effectiveness in promoting both language development and cultural learning.

In conclusion, digital 3D models hold considerable promise for enriching foreign language teaching, particularly by fostering learner engagement and cultural immersion. However, their current underutilization can be attributed to several barriers, including limited awareness among educators, a lack of appropriate content, and the challenges associated with producing and integrating 3D materials into classroom practice. With increased visibility, targeted resource development, and continued empirical investigation, digital 3D models could become a valuable component of the foreign language teaching toolkit.

In light of the findings, several recommendations can be made for educators, researchers, and policymakers to support the effective integration of digital 3D models into foreign language education. For educators, it is important that teacher education programs incorporate practical training on how to design and implement 3D learning objects in classroom contexts. Such training would enhance teachers' digital pedagogical competence and confidence in using technology-based materials. Moreover, language instructors should be encouraged to integrate 3D models alongside conventional resources, particularly when teaching culturally rich or spatially complex content, as this approach can increase learner motivation and foster deeper intercultural understanding.

For researchers, further empirical work is needed to examine the pedagogical impact of 3D models on different aspects of language learning, including vocabulary acquisition, speaking, and reading comprehension. Interdisciplinary collaborations between linguists, instructional designers, and software developers could lead to the creation and evaluation of open-access 3D materials tailored to specific linguistic and cultural objectives. Such research would not only expand the theoretical foundations of technology-enhanced language learning but also provide practical guidance for educators and developers.

For policymakers and educational institutions, the findings highlight the necessity of integrating 3D-based learning resources into national and institutional digital education strategies. Supporting initiatives that provide schools and universities with the necessary hardware, software, and professional development opportunities would enable wider and more equitable adoption. By aligning educational policy, research, and classroom practice, stakeholders can work collectively to overcome current limitations and fully realize the pedagogical potential of digital 3D models in foreign language teaching.

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