# Designing for Multilingual Conceptual Learning in Immersive VR environments: Teachers' Didactical Strategies in Study Guidance

DFL

COLLECTION: DESIGNS FOR LEARNING CONFERENCE: CONCEPTUALIZING DESIGN

RESEARCH

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## ABSTRACT

This study explores multilingual study guidance (MSG) teachers design for learning and the potential of immersive and interactive Virtual Reality (VR) technology to support students' development of disciplinary knowledge through multilingual conceptual learning. Part of a co-design research project, the study draws on two teachers' didactical designs and their creation of subject-specific VR environments, as well as their reflective evaluative discussions. Framing teaching and learning as a matter of design for learning combined with a meta-thinking framework supporting planning and evaluation of didactical designs, the participating teachers identified learning targets, how to teach, and how to organize each activity. Findings reveal that the teachers employed multimodal, dialogic, and experience-based approaches to co-construct disciplinary knowledge and language in contextually rich VR environments, stimulating critical thinking and promoting multilingual metalinguistic awareness. Despite the potential of immersive VR for inclusive and equitable learning, the study highlights a critical need for structured collaboration between MSG and subject teachers to ensure pedagogical coherence and curricular alignment. These insights contribute to the growing discourse on immersive learning design and its implications for multilingual education.

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## INTRODUCTION

Virtual Reality (VR) exemplifies a technology offering potential for immersive and interactive learning allowing students to experience destinations and content in three-dimensional (3D) format that goes beyond the classroom (Poupard et al., 2025). An increasing number of teachers incorporate VR into their teaching activities in schools due to technological advancements that have made VR-equipment more affordable and accessible (Maas & Hughes, 2020). Moreover, research highlights that VR can support the visualisation of abstract phenomena, thereby enhancing students' conceptual understanding (Yildirim et al., 2020). Teaching in these novel, VR-enhanced environments requires teachers to innovate by developing new pedagogical strategies and activities that support immersive teacher-student interaction (Mills et al., 2019). This entails a shift away from teacher-centered instruction toward activity-based learning (Beetham & Sharpe, 2020), empowering students to take greater responsibility for their own learning through carefully designed, student-centered tasks (Sun, 2017; Selander, 2022). This gained responsibility makes students invest in learning, selecting support tools and revisiting activities as needed (Meri-Yilan, 2019). Moreover, access to diverse digital and interactive resources necessitates supporting students in expressing their knowledge through multimodal means and recognizing their meaning-making processes as key indicators of learning (Bezemer & Kress, 2016).

This study has a particular interest in how teachers' design for learning in immersive VR environments with head-mounted displays (HMDs) contributes to the development of multilingual students' subject-specific knowledge during study guidance. Multilingual study guidance (MSG) in students' first language is a support that exists in Swedish schools to enhance the development of students' learning to meet the knowledge requirements of the curriculum (Skolverket, 2023). This raises the question of how to optimally organize learning activities with VR environments in instructional settings to support this multilingual learning in meaningful ways.

### MULTILINGUAL STUDY GUIDANCE ENHANCING SUBJECT-SPECIFIC KNOWLEDGE

MSG is a Swedish phenomenon that does not exist in a similar form in other countries (Rosén et al., 2020). The role of MSG teachers can be compared to what in international research studies is referred to as multilingual classroom assistants (Dávila & Bunar, 2020) or multilingual teaching assistants (Fritzsche & Kakos, 2021). The implementation of MSG in Swedish schools differs significantly across municipalities, with support being offered either before, during, or after regular lessons (Roux Sparreskog, 2023). The teaching, however, should still be aligned with the curricula and subject syllabuses of various school subjects.

According to Rubin (2019), the development of subject knowledge and language is an integrated process. Consequently, subject-specific instruction plays a crucial role in fostering students' language development and understanding across school subjects (Schleppegrell, 2012). Regarding multilingual students, Cummins (2018) shows that they benefit from consolidating concepts and content related to a specific subject in both their first language and the language of instruction. According to Reath Warren (2016), MSG supports the development of students' subject knowledge by giving them the opportunity to explain and discuss the content. Similarly, Jakobsson and Kouns's (2023) study on subject-language perspectives on multilingual students learning in science highlights the importance of dialogue where students have the opportunity to develop and refine subject-specific language in MSG.

Hajer and Meestringa (2014) highlight the difficulties that arise when MSG teachers simplify language and concepts, as this can reduce students' chances of grasping subject content and subject-specific concepts. This in turn affects the continuity of students' learning (Karlsson et al., 2020). To address these challenges in MSG, Karlsson et al. (2020) suggest including multimodal resources to illustrate abstract content and concepts. Similarly, Rosén et al. (2020) observed that multimodal resources played a central role in MSG instruction, with MSG teachers using information from the internet, YouTube videos, and translation tools in their teaching. In cases where MSG teachers did not have a computer connected to the Internet, they used their personal phones to access these resources.

### TEACHING WITH AND IN VR ENVIRONMENTS

VR enables users to engage with and navigate simulated environments as they were real creating a full-body experience in a simulated 3D world. This immersive experience is facilitated through the use of specialized equipment such as HMDs, motion tracking systems, and interactive devices like data gloves, all coordinated by advanced software (Chang et al., 2024; Lin et al., 2024). Teaching with VR enables teachers to simulate real-world scenarios engaging students in active, hands-on tasks manipulating objects (e.g., moving parts in a simulation), generating content (e.g., creating responses, building models) and engaging in dialogue (e.g., discussing, debating, collaborating) (Conrad et al., 2024). Applying this realistic technique promotes active and constructive learning that can be customized as an additional learning environment to fit specific educational needs, from virtual laboratories to historical reenactments (e.g., Lin et al., 2024; Żammit, 2023). Students can actively engage with content in VR environments that allows them to observe, communicate and reflect upon the acquired knowledge in the simulated situation at their own pace practicing what they learned in the situation (Lin et al., 2024) and revisit challenging material until they achieve mastery, thus supporting personalized learning (Żammit, 2023). Moreover, VR environments can also bring together students from different geographical locations in a shared virtual space, fostering collaboration and discussion. This shift from passive to active learning promotes critical thinking, problem-solving, and collaboration skills (Marougkas et al., 2023).

Research indicates that HMDs can increase student engagement, with learners investing more effort and time in simulations (Jensen & Konradsen, 2018). However, increased engagement does not necessarily translate into improved learning outcomes (Makransky & Petersen, 2021). The effectiveness of VR depends less on the technology itself and more on how it is pedagogically integrated and designed (Alam & Mohanty, 2023; Mills et al., 2019). VR environments typically incorporate multiple modes of representation, such as 3D models, animations, text, and audio, which require careful consideration of the cognitive load imposed on students (Makransky & Petersen, 2021). A recent study by Alam and Mohanti (2023) demonstrated that incorporating textual cues and summarizing support in VR-based instruction on area and volume improved primary students' learning performance and mental models without increasing cognitive load, underscoring the pedagogical potential of well-designed VR environments in mathematics education. In this context, VR's multimodal features can function as powerful pedagogical tools that enable students to participate in realistic simulations (Poupard et al., 2025), manipulate virtual objects (Liu et al., 2020), and explore complex concepts in immersive, experiential ways (Mills et al., 2019). Nonetheless, challenges remain, including reports of motion sickness associated with HMDs (Alam & Mohanty, 2023) and technical difficulties, which can make VR-systems cumbersome and time-consuming to implement effectively (Parmaxi, 2023).

## LANGUAGE LEARNING IN VR ENVIRONMENTS

The illusion of being physically present is also beneficial for language acquisition, practicing speaking in culturally authentic environments which can enhance communication and cultural skills (Chen et al., 2022) and lead to increased student engagement (Fryer et al., 2020). A meta-analysis of 21 studies conducted by Chen et al. (2022) underscores VR's potential to support language development, particularly in speaking skills, followed by listening comprehension and vocabulary acquisition. Through 3D, immersive interaction, students are stimulated to listen, comprehend, and respond in the target language, while also practicing pronunciation and expanding vocabulary (Soto et al., 2020; Sydorenko et al., 2018). Research shows that students interacting with 3D avatars and objects in immersive VR environments learn new vocabulary more accurately and quickly (Legault et al. 2019). Regarding conceptual learning, Liu et al. (2020) showed in a quasi-experimental study with 90 middle-school students that immersive VR-assisted science instruction significantly enhanced students' understanding and retention of scientific concepts compared to traditional classroom methods. Especially multilingual students may benefit from VR-enhanced science instruction, that according to Ding (2024) offers equitable access to conceptual understanding through multimodal meaning-making, visualizing complex scientific processes, and enabling sensorimotor engagement with materials and concepts.

The recognition in second language learning of communicative and social approaches over form-based grammar teaching, emphasize meaningful, interactive, and task-based use of language, grounded in principles such as authentic input, noticing on form, individualized feedback, and learner engagement in real-life contexts (Ellis et al., 2020). Godwin-Jones (2021) aligns the opportunities for real use of language in the VR-interactions through multimodal and embodied communication to language pragmatics (González-Lloret, 2019). Such interactions expose students to authentic communicative practices and facilitate learning beyond grammar and vocabulary, e.g. through encounters with misunderstandings, which serve as emotionally salient and pedagogically rich experiences. This implies learning language in patterns of usage based on adequacy and appropriateness in the context rather than focus predominantly on language complexity, accuracy, and fluency (Duek, 2017). For students this entails active, experiential and inquiry-based learning (Mills et al., 2019) with insights into specific use of constructions as well as into metalinguistic knowledge of how language works (Godwin-Jones, 2021).

Based on the outlined findings from previous research, while VR is increasingly being used to support student' conceptual understanding and language acquisition, research reveals significant gaps in our understanding of how immersive VR design influences learning (Parmaxi, 2023) and teachers' pedagogical practices (Mills et al., 2019). Moreover, studies indicate that teachers often lack sufficient knowledge about how to organise teaching with VR in educational contexts (Yildirim et al., 2020). These findings highlight a need for research that not only examines the pedagogical potential of immersive VR, but also explores how teachers engage in didactical design within such environments. This study builds on these insights focusing on how teachers' design for learning in immersive VR environments with the use of HMDs contributes to the development of students' subject-specific knowledge in the context of multilingual study guidance. The study is guided by didactical design theory emphasising the content-student-technology relationship exploring teachers' didactical designs and strategies in relation to the following research questions:

1. How is the work organized regarding alignment between knowledge content, activities, spaces, and resources?
2. What patterns of didactical design strategies do teachers plan for, re-evaluate and re-design for to enhance students' subject-specific knowledge multilingually?

## METHODS, THEORY AND MATERIALS

The following describes the theoretical framing, research design and participants including data collection, data analysis, and ethical considerations.

### STUDY DESIGN AND PARTICIPANTS

The present study is part of a co-design research project, *The use of adaptive VR environments to support students' learning in multilingual study guidance* (VRiS, 2022–2024), involving researchers, MSG teachers, their students from three schools in the same municipality, with the support of an ICT-teacher and a VR-designer in collaborative, iterative and reflective development (Schön, 1987) of educational activities in real classroom situations (e.g. Cviko et al., 2015). Previous studies have successfully merged action (Elliott, 2020) and design-based research (DBR) methods (McKenney & Reeves, 2019; Majgaard et al., 2011) promoting practical and theoretical empowerment in local contexts. While action research prioritizes participant ownership in the development process, DBR emphasizes theoretical advancements by formulating "small" theories related to enhanced teaching practices and user involvement (McKenney & Reeves, 2019). Considering the complexities of novel learning environments such as VR, this approach enables systematic and iterative framework to plan and evaluate didactical designs comprehensively to understand changes in the created learning environment (Sun, 2017).

The research design was conducted as a cyclic process of interventions with initial understanding of the problem identifying relevant assignments aligned to the needs and experiences of participating students as well as organizational and technical challenges of integrating new technology in teaching, scheduling, etc. (exploration phase, 1st cycle; McKenney & Reeves, 2019). These experiences informed the subsequent creation of new designs (re-designing) of learning tasks jointly discussed and reflected upon during a collaborative workshop and implemented and tested in classroom settings (construction phase, 2nd cycle). In the final evaluation phase (3rd cycle) the joint workshop was devoted to analysing and reflecting upon the implemented designs for learning in created VR environments and the overall changes in the teaching and learning environment. These workshop-driven activities generated data in the project consisting of teachers' didactical designs and audio recordings of reflective discussions. Also, the teacher-created VR environments were used as stimulus material in the reflective discussions. Observations of selected teaching sequences generated field notes and retrospective interviews with teachers and students.

Two MSG teachers participated in the two-year long project, one in Arabic (T1) and the other in German (T2), working also as first language teacher in German. Additionally, the study included five students (aged 9–13): two with Arabic and three with German as their first language. Four of the students have attended only Swedish schools, while one student, whose first language is Arabic, completed the initial years of schooling in his home country. The students received MSG from the teachers on regular basis, between 40 minutes to one hour per week.

The participating teachers utilized diverse VR-tools (e.g. Spatial, Meta Horizon Workrooms, Mozaik Digital Education and Learning) to create 3D objects, include multimodal resources (e.g. images, film clips, sticky notes) and to design own immersive VR environments with the use of HMDs (Meta Quest 2 and 3). One of the teachers conducted teaching remotely, while the other taught in person, sharing the same physical space with the student. During the teaching activities, both the teachers and students were present in the teacher-created VR environment wearing HMDs, interacting with one another as avatars. One of the teachers had prior experience to create and use VR-technology with students, while the other teacher and students had no such experience at the beginning of the research project.

The data presented in this study are based on the final implementation (2nd year) of the participating MSG teachers' didactical designs, recordings of selected teaching activities in the teacher-created subject-specific VR environments and reflective evaluative discussions (106 min of audio recording) in workshop-driven activities (3rd cycle). In this workshop, the reflective discussions among the MSG teachers and researchers focused on the implemented didactical designs applying the six specific categories in the design of teaching sequences and learning activities as analytical tool: 1) what specific subject content (knowledge goals), 2) why these learning objectives (competence), 3) when will activities take place (time), 4) where will activities take place (space) 5) which learning materials (resources), and finally 6) does this design supports learning (added value) (Sofkova Hashemi & Spante, 2016; Sofkova Hashemi, 2022). The discussions revolved also around the recurrent and successful didactical strategies, and the added values of VR-mediated education.

### THEORETICAL FRAME AND ANALYSIS

Framing teaching and learning as a matter of *design for learning* (Selander, 2022), we introduced the participating MSG teachers to a meta-thinking framework, called

Design Dice, supporting the planning and evaluation of didactical designs in workshop-driven activities (Sofkova Hashemi & Spante, 2016). The framework brings forward the content-student-technology didactical relationships shifting focus from the primary questions of teachers of which technology to use to a critical and activity-based alignment. This three-dimensional meta-thinking tool expands the fundamental components of 'didactic triangle' linking student, teacher and content (Biggs, 1996; Krogh et al., 2021) with new didactical relationships that arise with technology, space and time (Sun, 2017). With the aim of illuminating the didactical strategies employed by teachers in creating 3D materials and other resources to design subject-specific learning spaces in immersive VR environments from a multilingual perspective, the analysis involved examining the alignment between knowledge content, activities, spaces, and resources (Biggs, 1996; Biggs & Tang, 2011). The workshop-driven activity revolved in reflective discussion around the didactical designs of particular teaching sequences using the VR environments the teachers created and video-recorded lessons as stimulated recall (Lyle, 2003). In that, the teachers discussed their teaching intentions and motivations for the targeted knowledge content, as well as their choices of resources, spaces, activities and the design of learning materials within the implemented didactical designs.

### ETHICAL CONSIDERATIONS

The study follows the Swedish Research Council's (2024) ethical guidelines, including requirements for confidentiality, consent, information, and autonomy. All participating teachers and students were informed about the aims of the project, the purpose of data collection, and how data analysis would be conducted. Authorized letters of information were signed by the students' parents, where information was given about voluntary participation, the right to end the participation at any time, the safe-keeping of the data, and the anonymization of all participants.

## DIDACTICAL DESIGN STRATEGIES: THE CASE OF GREENHOUSE EFFECT

During the final phase of the project the teachers created three to four subject-specific VR environments. Teacher 1 (T1), who meets regularly with students at their school, designed VR environments for year 7 students focused on content in chemistry and biology. Topics included atoms, electrons, and nuclear particles; the conversion of hydropower into energy; climate change; and the greenhouse effect. Teacher 2 (T2), who works remotely with two students in years 4–6, also developed VR environments in science that addressed: the solar system; classification of substances and materials based on solubility, conductivity, acidity, and alkalinity; as well as biodiversity, organism adaptation, and local food chains and cycles. This section presents one of the T1s didactical designs on greenhouse effect with the aim to develop language and subject-specific concepts in the knowledge area of chemical processes and environmental awareness engaging a 13-year-old student in year 7. T1 and the student had established a working relationship prior to the project and worked together with immersive VR with HMD during the whole project time. The student was well-familiar with the VR-technology, comfortable and confident to speak in first language (Arabic) and language of instruction (Swedish). Data analysis is based on the teacher's planned didactical design for this subject matter applying the design categories in the Design Dice meta-thinking tool, the teacher-created VR environment in Spatial software, and lesson observations.

### DESIGNING FOR MULTILINGUAL STUDY IN CHEMISTRY

In the didactical design in Table 1, content and abilities connected with the subject of chemistry are shown in accordance with the design categories in the Design Dice meta-thinking tool. The core knowledge concerns the greenhouse effect and the related chemical processes in soil, air and water. An additional knowledge goal is language development in Swedish language and first language. The teacher distributed the design over three lessons (a 45–60 minutes) over a period of three weeks. The activities were planned to take place in the physical classroom and a VR environment created by the teacher using the Spatial software. The teacher planned and designed learning resources for the student to explore and interact with 3D models, static images, sticky notes and a short film. The added value of this design for learning, according to the teacher, is that the VR environment allows visualization, interaction and manipulation of concepts and processes.

### IMPLEMENTATION IN THE VR ENVIRONMENT

In the first lesson, the teacher had planned to revisit the concept of the greenhouse effect through dialogue. To support the repetition of previous knowledge and to encourage the student to talk about his own experiences with the knowledge content, the teacher used two 3D models of greenhouses from different programmes. One already existing model from an integrated programme in Spatial and the other 3D model the teacher generated from a prompt in an AI programme, both placed in a separate section in the VR environment (see Figure 1). The teacher's choice of the two 3D models was motivated by the fact that it would be possible to walk inside them and see what they looked like from the interior. During the second and third lesson, teaching took place in another section of the VR environment where the teacher had put two pictures and a short film on the

| **KNOWLEDGE GOALS**<br>**WHAT IS THE KNOWLEDGE CONTENT?** | **COMPETENCE**<br>**WHICH ABILITIES SHOULD BE DEVELOPED?** | **TIME**<br>**WHEN WILL ACTIVITIES TAKE PLACE?** | **SPACE**<br>**WHERE WILL ACTIVITIES TAKE PLACE?** | **RESOURCES**<br>**WHICH LEARNING MATERIALS?** | **ADDED VALUE**<br>**DOES THE DESIGN SUPPORTS LEARNING?** |
|---|---|---|---|---|---|
| Chemical processes in soil, air and water; connection to environmental and health issues.<br>The concept of the greenhouse effect and related concepts and processes.<br>Language development in both Swedish and first language. | To use chemistry concepts and explanatory models to describe and explain relationships in nature, society and the human body.<br>To communicate and discuss about the greenhouse effect and related concepts and processes. | In classroom:<br>- read and look together at the material covered in regular teaching<br>In VR environment:<br>- start with green house models<br>- continue with specific concepts | Classroom:<br>reading material<br>Spatial VR-environment divided into sections:<br>1. 3D models<br>2. pictures with sticky notes, or film | 3D models<br>Pictures<br>Sticky notes<br>Short film | Visualisation, interaction and manipulations of concepts and processes. |

**Table 1** Didactical design chemistry: The greenhouse effect.

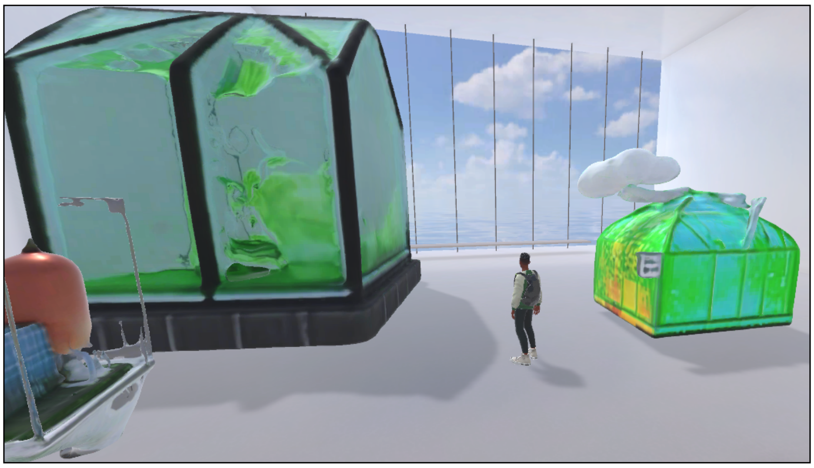

**Figure 1** Greenhouse effect VR environment: section with 3D models of greenhouses.

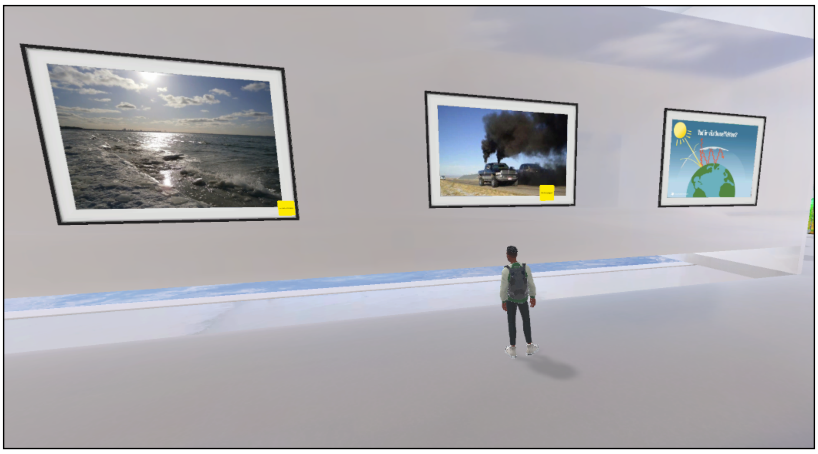

**Figure 2** Greenhouse effect VR environment: section with a short film and pictures with sticky notes on the albedo effect, anthropogenic and the greenhouse effect.

wall (see Figure 2). The two pictures were accompanied by sticky notes addressing selected concepts. One picture shows an ocean where the sun is reflected in the water and has a sticky note with the concept of *albedo effect* in the margin. The teacher planned to use the picture to discuss climate change, for example what happens when the icecaps melt. In the other, the word *anthropogenic* is written on a sticky note in the margin of an image of a large car emitting fumes. The teacher aimed to use this picture to illustrate the environmental impact of exhaust fumes. The short film is about the greenhouse effect and was chosen because it clearly and in limited time explains the solar radiation and greenhouse gasses. The film was about one minute long.

## TEACHERS' DESIGN INTENTIONS

Turning to the analysis of the teachers' reflections and evaluation of conducted designs for learning, we present here the analysis of the audio recorded reflective discussions from the final workshop in relation to the MSG teachers evaluation of knowledge content, activities, spaces, and resources in their conducted teaching designs created in immersive VR environments.

### KNOWLEDGE CONTENT

The teachers address knowledge goals and content in the subject of science: climate, energy and water. The analysis reveals the teachers' alignment to the knowledge content using relevant concepts for the student to learn that in case the teacher lacks access to the required study material from the class/subject teacher requires them to prepare and find free educational materials online to fill in the gaps and to complement with the material in the first language:

> *In this case, I didn't have that book; I only had the fourth-grade book, and it wasn't in there. Then I go and search if there is other free material on the net, either posted by colleagues or if there is something like this page, samples are sometimes available … And I look to see if there is German material. (T2)*

The teaching strategies the teachers deploy concern elaboration on specific concepts and posing questions to students, as in this quote regarding animals' adaptation to climate:

> *And hot then what makes it hot? Yes, the fur [on polar bear]. And why do you think he is white? Yes, adaptation. Why does their fur turn white when there is snow and we have talked about that. (T1)*

They also show examples of making connections to the geographical area in which the teacher's and student's home country is located, here when discussing air pollution:

> *When the sunbeam shines and the sun's heat enters the greenhouse but it doesn't bounce back but stays inside and what happens in countries, like Cairo when you fly into the city, you don't see the city up close because there is smog that makes one not see. (T1)*

It is the processes of some phenomena that are also in focus as the example above, demonstrating **in the moment** and preparing the student how to articulate their answers, reflect on different scenarios, problems, weigh up the advantages and disadvantages. This entails while talking about something in the VR environment to spontaneously show or demonstrate something related to the conversation in real-time:

> *Because inside VR if we talk about something, something comes up that I want to* ***show at the moment****, then inside VR I want to be able to go in and google something and it should come up … For example I want, I'm going to show you Antarctica when this great ice begins to melt. What happens then and how it can affect the animal life there, that are adapted to this cold and so on. Or go to YouTube and search for Antarctica and you will see some film clips that show it. (T1)*

In regard to language acquisition, the teachers apply a multilingual strategy ensuring the development of the knowledge content in the student's first language elaborating verbally on the concepts and phenomena and align it to the language of instruction in writing (sticky notes) and with the use of 3D models to visually illustrate the concept:

> *Because if I say the word greenhouse in Arabic, for example, then he might not understand it properly because he hasn't had time to experience it in his first language in his home country. Maybe he hasn't seen it. but if I show that this is a greenhouse [goes to the greenhouses in the VR environment] and explain it in Arabic. I could have also said it in another language so he could learn it. Then it becomes much easier to learn when you see greenhouses. (T1)*

> *And then I say the concept in Swedish and the explanation in Arabic and then we have it [the 3D model] in front of us. (T1)*

The teachers' emphasis on both understanding the material and expressing it in the language of instruction requires strategies to approach the subject matter in the first language:

> *Then she has started with the subject in the usual teaching in Swedish, so maybe she has the concepts and can say them in Swedish then. Often, she doesn't know them in German. Or we have talked and she has been able to explain what she has learned in the lesson. (T2)*

### ACTIVITIES

The reflective discussions mainly concern the teachers' experiences of the activities during the lessons together with the student in VR with HMDs revealing also their teaching intention. The teachers addressed what activities they designed for and what activities they observe happening when they are together with the student in VR as avatars. T1 invites students to talk in their first language designing for activities in interactive dialogue with the subject content and visualizations of central concepts and processes activating the student to ask questions and to see:

> *We were first going to talk about the greenhouse effect and I thought there should be as much **discussion** as possible. I want him to talk and he did. We have **discussed and I ask questions** and **he asks questions** and he is more involved with me than in the lesson [ordinary classroom teaching]. I think that it is a big plus. When we finished talking about the greenhouse effect, I said look here, we'll go and **look at these concepts or these pictures and then I'll explain to you more**. By looking at the pictures and talking, **he will see what I mean** and then it will be much easier for him to understand and then he will ask a question and I will answer and so on. (T1)*

T1 also encourages her students to interact with the resources in the VR environment and describes how one student manipulated a 3D object of a polar bear:

> *He took it [the polar bear] and lifted it up and made it bigger and smaller and spun it around. (T1)*

T2 reveals aiming at face-to-face dialogue in conversation with the student that feels more natural when facing each other:

> *In the Workroom [the software], she sat next to me, so we both could see the board, but I noticed that when she was talking to me, I would turn and look at her avatar, and she would look at me, making it feel more real in the Workroom. (T2)*

T2 elaborates on her reasoning, showing how she thinks more about the focus of shared attention (object, looking at each other):

> *When we talk now, we should face each other, meaning we look at each other, and so on. I think it's something you can practice, and if, for example, we were to find an object together and I showed her "this is here", then she would be standing next to me and looking at the object. (T2)*

## RESOURCES

The teachers discussed how the affordances of various VR environments influenced their didactical designs and choice of resources. Most of the activities took place in the VR environment, though T2 works on distance, depended also on the comfort of the student:

> *Zoom is really just an extra support not to lose each other. … It was really just as an extra resource and it was also the case that she expressed at the end that she had a headache and then we decided to get off the headset and then we could continue on Zoom. (T2)*

Whereas one software allows for integration of video resources other require them to use film clips outside the VR environment:

> *Yes, well, it also depends on what I want to show. In this case, I found short clips in German that explained the first steps with solutions and mixtures, and we could watch them in Spatial. But in Workroom, that wasn't possible. So, we had to watch it first. Meaning, first Zoom, then YouTube, and then Workroom. (T2)*

Functionalities in the software may develop but also change:

> *When I'm in here, I want to search online and I want to go into Safari and search for an image and it worked a year ago but not anymore. (T1)*

The dependence of internet connection is highlighted:

> *… a well-functioning Wi-Fi is required. (T1)*

Time is also addressed as an obvious resource of which there is too little, which influences the choice of VR environments to work with. The teachers have on average two hours per week for planning which requires effectiveness:

> *When I sit and plan I don't have a lot of time and to research something new, it can take several hours. But I don't have much time. So Spatial I know how it works and it goes very fast. (T1)*

Visual resources play a central role to clarify and understand subject matter engaging the students in drawing or choosing objects depended on the various affordances in the VR environments:

> *She talked about how they had mixtures with sugar and water and how it dissolves, and then she **drew some sugar cubes**, just to **reinforce** it with simple images.* (T2)

The quality of visual resources and how realistic they are influence the experience:

> *But it happens that when you enlarge the models, the quality of the image drops – on that model, it becomes so blurry. It blends together. (T1)*

> *She [the student] always removed the ones that looked very **pixelated**, that is the ones with poor resolution and the ones that were **drawn**, so she wanted the ones that were **more realistic.*** (T2)

The added value of 3D objects aligns to the choice and manipulation of them rather than activating students to draw them on their own:

> *It is possible to draw in Spatial as well, but it will be **three-dimensional** and we tested that at the beginning and it was very **difficult** to achieve it, as if you look at it from another direction it looks completely different, so it didn't turn out in much drawing for her. There it was more that we picked out 3D models then to make it pictorial. That you have it as support for words.* (T2)

The teachers encourage students to see connections between the objects and concepts by themselves and contribute and expand the subject matter they are working with choosing also critically among relevant objects:

> *I had put some plants, trees and then the concepts that belong to a food chain and then we talked about **what she saw and how they could be connected** and so on, but then she had more examples of food chains, so we took them too and put in.* (T2)

> *There are a lot of 3D objects from the game world and then she has to select them out so that it will be **as realistic as possible** so that she understands that this made-up-knight that's not how they looked like, that she can **distinguish** between the objects of the game world and that which **belongs to the subject.*** (T2)

Activating students choosing among objects and colours is by the teachers interpreted to support their understanding:

> *She could also sometimes choose something that was **sweeter**. I know that one of the birds at the time was a little chick and then it was cuter so then she took it and: "Oh this one is cute. Yes, we will take it", but I think that as long as **she chooses** then she **will remember** that picture better than if i choose.* (T2)

> *If she wanted **a red bird** instead of a black one, it was easier for her to understand then in this food chain.* (T2)

## SPACES

The teachers reflect on the created 3D environments enabling long distance movements when elaborating on for example why it snows on the North Pole and why a polar bear has a white fur and what will happen if the bear moves from North Pole to Australia where it's warm, what makes Australia hot? Movement between the 3D portals can ensure other sensations of being in the moment, here in relation to exploring further the weather phenomena on earth:

> *Now then how does it feel now, for he **jumped** into the rainforest ... So here you are. How does this feel then? And I promise that when you are inside then you can almost **feel this warm wind**. (T1)*

Experiences from spaces in real life are brought to the floor:

> *And then I asked the student **if he has ever been inside** a greenhouse and he did, when you buy vegetables in a greenhouse or something like that. And then I asked him how did it felt, what did you think: It's hot, it's stuffy, he said. And then we start from that, his own experience with greenhouses and then we talk about it. (T1)*

The 3D spaces create memories, according to the teachers, which compared to demonstrating the same phenomenon elsewhere would not have the same effect:

> *That's what he tells the teacher, that I have it much easier [in the 3D space] because when I sit and write **I see this image** that we have been looking at. **I remember that occasion.** He relates it: Yes, that's right. That's when we jumped in VR and then I felt it in my stomach and we were in front of the greenhouse. He associates slightly different memories with each other and remembers. (T1)*

## DESIGN PATTERNS

The teachers' intentions for design of learning tasks and the VR environment reveal distinct patterns in regard to subject knowledge and multilingual language acquisition. T1 designs for learning with the point of departure largely about the student's previous experiences in order to create optimal conditions for, above all, language learning. The activities that the teacher tells about that are carried out during the lesson (by the student or by T1 and the student together) are focused in dialogue-based learning strategies: that they talk and discuss different subject matter topics and concepts, that they ask each other questions, etc. But also, that they laugh and have fun together, something T1 emphasizes is important for learning. T1 also returns to the importance of the experience-based learning, noting that VR provides this in a way that other technology-mediated environments do not do in the same way. The teacher also highlights limitations in the VR resources, such as environments with fixed templates that only allow changes in color or object placement. Additionally, T1 points out technical shortcomings, like the inability to search the internet or play specific film clips synchronously, features that previously worked but no longer do. Also, the apparent use of the free versions of software, rest in itself has limitations which in turn affects planning and implementation.

Also, the didactical strategies of T2 invite to constant dialogue with the teacher's primary focus on word and concept understanding in both languages designed in varied tasks with the support of visual elements. T2 also reveals devoting significant time for preparation of the VR environment based on the affordances of different software and available resources. The 3D possibilities in Spatial activating the student require more control from the T2 in the design. In Workroom promoting more natural dialogue demands prior preparation such as downloading images and other resources into the VR environment.

## DISCUSSION

The analysis shows that the MSG teachers employ varied pedagogical and multimodal strategies in their design for learning in VR environments to facilitate students' understanding of language and scientific concepts, often conditioned by the access to instructional materials provided by subject teachers. In determining which knowledge to prioritize, the teachers communicate subject content through various strategies: they use questions to spark thinking (inquiry-based), connect and work around key concepts (integrative), or draw on students' prior experiences and backgrounds to build connections (constructivist). In addition, both teachers use multimodal resources in their language teaching by highlighting key concepts in Swedish (the language of instruction) and engaging students in speaking, listening, and reading, while also providing explanations in the students' first languages. This creates opportunities for a multilingual learning environment (Ding, 2024).

Furthermore, the results show that both teachers, in their didactical designs, encourage dialogic and interactive activities in the VR environment. Aligned with communicative and social approaches to language learning (Ellis et al., 2020), they design task-based activities grounded in authentic input and noticing on form, emphasizing the importance of giving students opportunities to ask questions, engage in discussions, and refine both their subject knowledge and subject-specific language (Reath Warren, 2016; Jakobsson & Kouns, 2023). To create such learning environments, the teachers in this particular study focused on different aspects in their didactical designs. One teacher incorporated objects (e.g. 3D models, pictures and sticky notes) into the VR environment to encourage students to ask questions and speak. By moving between the objects together with the students, they practiced and deepened subject-specific concepts and processes. By engaging students in hands-on tasks through manipulating and exploring these objects, the approach contributes to activity-based learning (Beetham & Sharpe, 2020; Conrad et al., 2024), enabling students to take an active role in the learning activity and connecting concepts to the subject content (Lin et al., 2024; Zammit, 2023). The second teacher emphasised the importance of a VR environment that supports the sense of "real" face-to-face interaction, i.e. teacher and student looking at each other while talking. To achieve this face-to-face interaction with the student, the teacher mostly created VR environment resembling a physical classroom consisting of a whiteboard (for writing and posting sticky notes) and a desk where they sit next to each other. The teacher thus prioritized familiar face-to-face interaction over the more exploratory, object-based, and student-driven practices, highlighting the critical gap between teacher intentions and implementation in a design for learning (Mills et al., 2019).

The teachers employed visual elements in the design for learning as a central resource when clarifying concepts, guiding students and activate engagement through drawing and critical object selection. They link these visual strategies to students' learning processes connected with remembering a specific picture or simulation, or choosing colour. Similarly to Alam and Mohanty (2023) study of textual cues and summarized scaffolding in VR environments, the integration of written concepts on sticky notes alongside images and short films emerged as a valuable design strategy to support multilingual concept development. The teachers thus intentionally designed for experience-based activities, believing that aligning the environment with students' prior experiences enhances memory and facilitates learning. For example, a student standing by a greenhouse and looking into it in VR might trigger a memory of having been in such a place before, or a student being in a rainforest could evoke a sense of being in a tropical climate, providing opportunities for multimodal and embodied interactions (Godwin-Jones, 2021; González-Lloret, 2019). This aligns with Makransky and Petersen's (2021) cognitive-affective model of immersive learning, which emphasizes the careful balance between multimodal stimulation and cognitive load.

Additionally, the results show that the experience-based design promotes retention of knowledge through sensorimotor engagement, such as a student remembering content by physically interacting (jumping and moving around) in a VR environment. Our findings thus extend the evidence of Liu et al.'s (2020) quasi-experimental study into multilingual settings, where retention was supported not only by embodied VR experiences but also by multilingual scaffolding. Within this incorporation of a variety of multimodal resources to revisit and reinforce concepts (Karlsson et al., 2020), the teachers also acknowledged practical constraints, such as time, internet access, and software features, that shaped their didactical design choices.

Limited access to current subject content highlights a broader challenge, the lack of structured collaboration between MSG teachers and subject teachers, which has also been demonstrated in previous research (Engblom & Fallberg, 2018; Duek, 2017). The MSG teachers in this study expressed during the project their desire for better collaboration, which according to the Swedish Schools Inspectorate (Skolinspektionen, 2017) is necessary for successful MSG instruction. It is not enough to have a short conversation in the corridor or in the staff room, but an organized collaboration between MSG teachers and subject teachers is necessary. As shown in this study, the MSG-teachers create relevant lesson material themselves, which allows them to adapt the VR environment and activities to the needs of each student. Thus, how well the VR environment is adapted to the specific student depends also on the collaboration with the subject teacher, who has subject knowledge and insight into what the student needs to develop knowledge about in the current subject content. While international research has documented the affordances of VR for science (e.g., Liu et al., 2020) and language learning (Chen et al., 2022), our findings extend this knowledge by demonstrating how VR functions in the specific context of Swedish MSG. Unlike general classroom studies, MSG requires teachers to design for fair access to disciplinary knowledge across languages, confirming Cummins' (2018) emphasis on the integration of subject and language learning, but now situated within VR-mediated environments.

## CONCLUSION

The study demonstrates how teachers apply varied didactical designs in immersive VR environments with HMDs to strategically integrate multimodal, dialogic, and experience-based approaches that foster students' conceptual understanding and multilingual language development. Through immersive scenarios, visual and interactive elements, and language scaffolding across students' first and instructional languages, VR emerged as an expanded learning space (Lin et al., 2024) where subject-specific language and knowledge are co-constructed in contextually rich, task-based interactions (Jakobsson & Kouns, 2023; Cummins, 2018). Students engaged in receptive and productive language practices based on adequacy and appropriateness with teachers consciously employing tools such as 3D models, written cues, and images not only to visualize abstract concepts (Reath Warren, 2016), but also to stimulate critical thinking and promote multilingual metalinguistic awareness (Godwin-Jones, 2021). While their design choices differed, a shared commitment to engaging students in authentic, language-rich, and conceptually grounded activities was evident. Also, although the teachers emphasized different aspects of dialogic and interactive learning, they both used multimodal resources to support task-based activities with knowledge content and deepen students' conceptual understanding (Karlsson et al., 2020). The findings highlight the affordances of VR for inclusive, collaborative learning (Marougkas et al., 2023; Ding, 2024), demonstrating its potential to support equitable access to disciplinary knowledge through embodied, multimodal meaning-making. However, the findings also reveal a critical limitation in the lack of structured collaboration with subject teachers that often leaves MSG teachers to independently determine instructional focus and design content. While VR offers significant potential to support equitable, immersive, and multilingual learning, its impact depends not only on teachers' design skills, but also on the systemic support for interdisciplinary collaboration. Strengthening these collaborative structures is essential to ensure that VR-enhanced learning environments are both pedagogically sound and aligned with students' curricular needs.

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## COMPETING INTERESTS

The authors have no competing interests to declare.

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