Successful Teaching Strategies in Virtual World Education for Engineering and Computing

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***Abstract*—This research paper examines successful teaching strategies developed by educators in desktop virtual worlds (DVWs). These environments provide unique affordances for creating immersive learning experiences that exceed the capabilities of other online learning platforms. They are particularly valuable for engineering and computing education, where abstract concepts often present significant learning challenges.**

Given this potential for technical education, this study investigates two key questions: how experienced educators structure learning activities in DVWs and what teaching strategies best leverage the unique affordances of DVWs for learning. To answer these questions, we conducted in-depth semi-structured interviews with 14 educators from the Virtual World Education Consortium with extensive teaching experience in DVWs. Data were analyzed through thematic analysis focusing on identifying teaching strategies and implementation approaches that could be adapted for computing and engineering educational contexts.

Our analysis identified ten successful teaching strategies across three categories: Experiential Learning Strategies (including scenario-based learning and scale manipulation); Active Learning & Constructivist Strategies (such as spatial co-presence learning and structured exploration); and Social Learning & Community Strategies (featuring character-mediated instruction and multi-university collaborations). These strategies leverage unique capabilities of DVWs to implement approaches that would be difficult or impossible in physical or other online environments.

The findings provide practical guidance for educators without prior DVW experience and those seeking to implement DVW teaching in computing and engineering disciplines. The identified strategies demonstrate how virtual environments can enhance conceptual understanding of complex technical subjects, create authentic problem-solving contexts, and facilitate engagement through diverse activities, enhancing student learning experiences.

***Index Terms*—Virtual worlds, Virtual learning Environments, Instructional design, Interaction Design, Affordances, Pedagogical strategies, Active learning, Experiential learning, Social learning, Interactive learning, Virtual reality, Virtual labs, E-Learning, Engineering education, Computing education, Student engagement, Qualitative research**

I. Introduction

Compared to virtual reality, desktop virtual worlds (DVWs) offer one of the most accessible platforms for immersive education, requiring minimal specialized hardware while enabling extended student engagement in virtual environments. Furthermore, in contrast to other online learning platforms such as MOOCs, LMSs, or video conferencing, the spatial nature of these environments facilitates teaching methodologies that would be difficult or impossible to implement elsewhere. These distinctive characteristics make learning environments in DVWs particularly useful for engineering and computing education. In these technical disciplines, DVWs enable abstract concepts to be transformed into immersive interactive simulations that students can manipulate directly, facilitating learning through experience and practical application [1]. This approach directly addresses common challenges in these fields, including the visualization of abstract concepts, the need for hands-on experience, and the importance of collaborative problem-solving [2]. However, these environments typically exist within virtual worlds created for purposes other than education [3]. Thus, educators should adapt these platforms to serve their objectives, considering pedagogical adjustments that make these worlds useful and usable for teaching. Despite these adaptation efforts, best practices and methodologies in DVW education remain an evolving area of research, with many educators developing successful approaches through years of trial and error.

To address this need for established methodologies, our research explores two primary questions:

- How do experienced educators structure learning activities in DVWs?
- What teaching strategies best leverage the unique affordances of DVWs for learning?

To answer these questions, we conducted semi-structured in-depth interviews with 14 educators from the "Virtual World Education Consortium (VWEC)" community in Second Life (SL). Our participants were professors with extensive DVW teaching experience across various disciplines. Interviews were conducted simultaneously via Zoom and within SL, allowing educators to demonstrate their virtual teaching environments while discussing their practices. We performed thematic analysis on the verified transcripts with specific focus on identifying teaching strategies from different disciplines that could be effectively transferred to computing and engineering contexts.

Our analysis identified successful teaching strategies that take advantage of spatial and interactive features of DVWs. These approaches address persistent challenges in computing and engineering education by creating immersive experiences, facilitating active learning, and enabling collaborative interactions that would be difficult in other online learning environments.

The significance of this research lies in its identification of successful pedagogical approaches from a broad range of disciplines that can be specifically adapted for computing and engineering education. By documenting and analyzing these approaches, we provide computing and engineering educators new to DVWs with implementable strategies that address common challenges in these fields, potentially reducing the learning curve while improving student engagement and learning outcomes.

II. BACKGROUND

DVWs are interactive, dynamic and immersive 3D spaces that bridge the gap between theoretical knowledge and practical application [4]. These environments establish a middle ground between 2D web spaces and 3D physical classrooms, providing spatial opportunities for collaboration, and education. Unlike virtual reality that requires specialized headsets and often limits session duration due to user discomfort, DVWs function through standard computers with minimal hardware requirements, enabling extended learning sessions and featuring persistent environments that remain accessible whether users are present or not [5].

A. DVWs in Computing and Engineering Education

DVWs offer spatial characteristics that enable educational approaches that are particularly valuable for technical disciplines through their unique affordances [6]. Engineering education increasingly adopts these environments for their ability to create safe, cost-effective simulations [7]. Computing education benefits from these spatial characteristics in numerous applications. For example, in teaching programming, Singh [8] proposes students engage with the virtual environments where basic programming concepts are visualized spatially. By highlighting specific lines or segments of code, students can observe how these elements are represented and function within the virtual space, creating a direct visual connection between code syntax and its execution.

B. Challenges in DVW Learning Environment Implementation

Despite their potential, students' meaningful learning does not automatically occur in DVWs without appropriate instructional support and engaging teaching methods. Annansingh [9] emphasizes that instructors need to deliberately use the methods that stimulate students' spatial and critical thinking, curiosity, growth mindset, and active and experiential learning to maximize educational outcomes. Implementation challenges include significant technical overhead for environment creation, customization and steep learning curves for both instructors and students [10]. In addition to these, computing and engineering education faces discipline-specific challenges, including accurately representing complex systems, balancing visual representation with functional fidelity, and addressing the rapidly changing nature of technical fields [11]. Institutional barriers often include insufficient technical support, concerns about assessment integrity, and difficulty integrating with existing learning management systems [12]. Addressing these challenges requires grounding DVW learning environment implementation in robust pedagogical frameworks that guide effective teaching strategies to overcome these barriers.

C. Pedagogical Theories in Virtual Learning Environments

Active learning requires students to engage in reflective activities and apply concepts directly, demonstrating superior effectiveness compared to passive learning methods for mastering complex material [13]. Brame [14] identifies a range of active learning strategies, from brief discussion breaks to comprehensive case studies requiring critical decision-making. This approach requires students to produce demonstrable outcomes, helping assess understanding and reinforcing learning through direct experience.

DVWs enable experiential learning where students learn by doing rather than observing [15]. Studies have shown that learning outcomes in DVW labs are comparable to real-world labs [16], but with significant advantages: DVW labs are reusable, location-independent, and scalable, with lower investment and maintenance costs, and easy replication to meet educators' specific needs. They also create flexible contexts to encourage students' learning through direct experience [17].

Experiential learning is formalized in Kolb's experiential learning theory [18], which emphasizes learning through concrete experience, reflective observation, abstract conceptualization, and active experimentation. DVWs allow students to engage in all four stages of Kolb's cycle within immersive contexts that simulate real-world scenarios. As Vallance [19] argues, advancing education requires more active learning through experience—precisely what well-designed virtual worlds facilitate through their constructive possibilities.

Constructivism theory builds upon the active and experiential foundations by emphasizing that knowledge is not merely absorbed but actively constructed by learners as they reflect upon experiences [20]. While active learning focuses on engagement with content and experiential learning emphasizes learning through doing, constructivism specifically addresses how that engagement leads to the formation of mental models and understanding. Higher education has increasingly shifted from lecture-centered "instructivist" approaches toward student-centered constructivist methods that place the student's active meaning-making at the center of the educational process through social interactions and collaborative knowledge building.

Social dimensions of constructivism theory recognize that knowledge is built through both students' individual cognition and their social interactions [21]. The theory also indicates that learning is most effective when students create meaningful projects while exploring concepts. Students gradually build and refine their projects over time, with technology functioning as a tool that supports creation without becoming the focus itself. This principle is particularly relevant to technical disciplines like computing and engineering.

Engineering and computing education benefit significantly from these pedagogical approaches. In computing education, programming naturally aligns with constructionist principles through code creation, while distributed constructionism extends this to collaborative development and sharing of software projects [22]. For engineering education, constructivist approaches address the historical challenge of abstract conceptual understanding by connecting theoretical principles to tangible implementations. Engineering students in constructivist DVWs develop more robust mental models of structural mechanics compared to traditional instructional methods [23].

Traditional education typically positions students as passive recipients of instructor-delivered content [24], whereas constructivist approaches in DVWs actively engage students in knowledge construction through interaction in the simulations [25]. These virtual environments respond to students' diverse learning styles and build upon their prior knowledge, emphasizing engagement over passive reception [26]. This interactive approach particularly benefits technical disciplines where students need to develop both theoretical understanding and practical skills. In DVWs, students can safely interact with complex systems and observe relationships in real time. They can develop theoretical frameworks and test their hypotheses relatively quickly through experimentation [27]. The multi-user collaborative nature of these environments simultaneously enhances academic knowledge and social skills [28], creating a learning cycle that reinforces technical concepts while building essential collective problem-solving abilities and interpersonal competencies. By integrating these active, experiential, and constructivist principles, DVWs offer uniquely powerful learning environments for computing and engineering education.

Despite this recognized potential, actualizing these benefits requires appropriate pedagogical strategies that many educators struggle to identify and implement. While considerable research has explored the use of DVWs for education, there remains a need for studies identifying specific teaching approaches and strategies. Current literature often describes technological features or presents individual case studies without expanding into in-depth analysis of structured teaching methods for experiential and active learning in virtual world courses. Furthermore, limited research exists on adapting these teaching approaches to the particular requirements of computing and engineering education. This research aims to address these gaps by identifying transferable teaching strategies from experienced educators for successful implementation in computing and engineering virtual world environments.

III. Methods

To investigate successful teaching strategies in DVWs, we employed a qualitative approach centered on in-depth interviews with experienced educators. Our methodology was designed to capture both verbal descriptions and visual demonstrations of teaching practices within virtual environments.

A. Participant Selection

We conducted semi-structured interviews with 14 educators from the VWEC community in the SL. Participants were selected based on their extensive experience in teaching and creating virtual learning environments, with most having at least five years of DVW teaching experience. While participants represented various disciplines including computer science, biology, chemistry, astrophysics, linguistics, social studies, humanities, psychology, arts, and geography, we specifically focused on identifying strategies that could be effectively transferred to engineering and computing contexts.

B. Data Collection

Interviews were conducted simultaneously via two channels: Zoom for audio recording and automatic transcription, and SL for in-world demonstrations. This dual-platform approach allowed educators to verbally describe their teaching methods while simultaneously demonstrating them within their virtual campuses. Each interview lasted 60-150 minutes, with participants guiding us through their virtual teaching spaces and showcasing learning activities and environmental designs.

C. Data Analysis

We employed thematic analysis to identify patterns across interviews. Initial transcripts generated by Zoom were verified against audio recordings to ensure accuracy before coding began. The analysis process involved:

1) Open coding to identify all teaching strategies and pedagogical approaches mentioned by participants
2) Axial coding to group related codes into categories
3) Selective coding to identify core themes and strategic approaches

Through this process, we identified hundreds of initial codes that were ultimately organized into three main categories of teaching strategies. Within each category, we identified specific teaching approaches with demonstrated success in higher education that showed particular promise for application in computing and engineering contexts.

IV. Findings

Our analysis revealed ten successful teaching strategies across three categories: Experiential Learning, Active Learning & Constructivist, and Social Learning & Community Strategies. These strategies represent approaches that educators have developed and refined over time to capitalize on the unique affordances of DVWs. In the following sections, we present each strategy with supporting examples from our interviewed educators, organized by category.

A. Experiential Learning Strategies

1) Scenario-Based Learning with High-Stakes Consequences: This strategy transforms abstract concepts into vital knowledge through emotionally engaging scenarios with consequential outcomes. Rather than teaching concepts in isolation, educators embed them in contexts where application directly impacts meaningful results. One chemistry professor created a progressive bomb defusal scenario where students had to balance chemical equations correctly to escape rooms with decreasing time limits: *"A maze where the first room is...*

you've got 10 min to get out. And you have an easy one. The next room, there's 5 min and it's a little harder."

This scenario provides a template for time-sensitive learning challenges: *"You're locked in a room and the bomb is going to go off. You can stop it, but you have to figure out this problem."* This scaffolded approach creates an increasing, time-bound challenge while building skills incrementally. The learning tasks remained authentic to the discipline: *"they're still learning the process"* even as the scenarios created urgency. This approach maintained educational rigor while creating urgency for learning abstract concepts: *"Add a layer of vital to the knowledge so that it becomes more interesting; more important. And it makes a more indelible memory. Because you have something else reinforcing the need to know this information"* emphasizing how this approach transforms student perception: *"By creating situations inside the virtual world that we couldn't create in a classroom, we can make whatever it is we're attempting to teach important at the moment."* The findings further highlight the emotional component: *"having something at stake... makes students more focused to remember"* concepts that might otherwise seem abstract and disconnected from real-world application.

This approach can have direct applications for computing and engineering education. For example, in cybersecurity education, this approach could create scenarios where students should implement proper encryption protocols before a simulated data breach occurs. Software engineering courses could implement critical system failure scenarios where code directly impacts simulated human safety, mirroring real-world consequences of engineering decisions.

In civil engineering courses, students could encounter scenarios where they must identify and fix structural flaws in a bridge design under increasing load conditions. Time constraints add urgency, as the structure would collapse if defects remain uncorrected within the allotted time-frame. This creates an authentic context where theoretical knowledge about load distribution and material properties becomes immediately relevant to preventing a catastrophic outcome. The key to success is connecting abstract technical knowledge to consequential outcomes that create emotional engagement and experiential learning.

2) Mystery-Based Laboratory Design: This approach creates realistic scientific practice through unknown outcomes that mirror real-world research methodologies. Instead of laboratories with predetermined results, students encounter problems requiring the application of technical knowledge. For teaching general chemistry basics, one professor has designed forensic investigations based on a real case. This connection to real criminal investigations created greater student engagement than fabricated scenarios while teaching real-world processes: *"So a lot of my laboratories have been that kind of laboratory where there's a mystery or an unknown and you had to solve that... And so that has been my way of doing or way of engaging for a long time, is to give students "don't know the answer". You gotta figure it out. You gotta do the experiment and you got to figure out what's going on."*

This also parallels professional practice where solutions are not predetermined. For computing education, this approach could transform conventional programming assignments into code analysis where students investigate malfunctioning systems with unknown errors. Computer networking courses could present students with malfunctioning networks where they should diagnose and resolve issues without complete documentation, mirroring real-world troubleshooting scenarios. Engineering problems could similarly be framed as failure analysis cases where students should determine what went wrong through investigation.

The mystery framework harnesses students' natural curiosity, intrinsic motivation, drive, and the problem-solving skills that are central to both scientific and engineering mindsets. This strategy represents a fundamental shift from passive lessons to active experiences by creating a state of genuine curiosity that drives students' engagement. Educators design learning activities that trigger intrinsic motivation to discover rather than simply absorb information.

3) Scale Manipulation for Impossible Perspectives: This strategy enables students to experience environments at scales that would be impossible in physical education or other online learning modalities. Using their avatars, students can navigate through microscopic structures or explore macroscopic systems from the inside, creating an embodied understanding of abstract concepts. As one biology professor described their built brain model: *"a large model of the brain that your avatar could walk around inside and see the different elements.*

Another professor emphasized how this method creates a better understanding of the nature of the structures or systems: *"I personally tried... we wanted the system to be as close to reality as we could get... make the model as close to real as possible. It's gonna make them feel like they're there inside the system... and they can see what's happening between each element."*

This approach has powerful applications for computing and engineering education. For instance, computer architecture could be taught by allowing students to navigate through scaled processor models and observe data flow paths from inside. Network protocols could be visualized by having students follow packet paths through routers and switches. Embedded systems courses could enable students to "walk through" IoT device architectures, visualizing data flows from sensors through processing to actuation. Engineering students could explore stress patterns inside materials or fluid dynamics inside pipes, creating an intuitive understanding of phenomena typically represented only through equations or external visualizations.

4) Programmatically Accelerated and Randomized Results of the Experiments: This approach compresses time-intensive processes into manageable educational experiences while maintaining scientific authenticity. Unlike physical laboratories where certain processes might take hours or days to collect data, virtual worlds can accelerate these processes without sacrificing learning outcomes. While accelerating the processes, students are still informed about the actual time these processes would require to complete in the real-world.

As one professor explained: *"For time's sake, we speed things along. So if something would normally take a couple of hours, we go wzzzz and it goes really fast allowing students to produce the data... a lot more quickly than you could produce it in real life"*

Along with accelerating experiments, educators highlighted the value of randomizing generated data and results to individualize the learning experience. This individualization prevents students from simply copying each other's work in group projects while creating unique analysis opportunities. As one professor explained regarding individualized data generation: *"They each have to interpret their own data and come to reasonable conclusions from that... you're not all looking at the same results."*

This approach requires students to develop personal data interpretation skills while still working within a collaborative framework. For engineering and computing education, this dual capability of acceleration and individualization directly addresses the challenge of iterative learning. Software development life cycles could be compressed to allow students to experience complete project evolution in a single session, with each student or team receiving uniquely generated user requirements or testing outcomes. Specifically, this approach could compress release cycles that typically take weeks into single sessions, allowing students to experience multiple iterations of deployment and user feedback. Computer architecture courses could accelerate processor performance under different configurations, allowing students to observe optimization effects in minutes rather than hours of simulation time. Engineering simulations that might take days to run could be accelerated while preserving accurate outcomes, allowing students to test more design variations within course constraints. This approach maintains process fidelity while addressing practical time limitations.

B. Active Learning & Constructivist Strategies

1) Spatial co-presence learning: This method facilitates peer learning through strategic spatial positioning of student avatars, enabling them to observe classmates tackling similar challenges from diverse virtual perspectives. Via co-presence affordances, immersive environments enable knowledge transfer opportunities that other online learning platforms struggle to provide. Students can observe peers applying various problem-solving approaches, gain implicit knowledge through watching others, and engage in unplanned and spontaneous collaborations due to co-presence in the same shared virtual environment. One professor described this unique affordance:*"Because it's a 3D virtual world where students can see what's going on around them, they can make observations that will then in turn, help them perform the experiment or the process themselves... the fact that students are next to other students who are doing the exact same thing that they are, and they can look over and see what they're doing."*

Another professor highlighted this distinction from conventional online learning: *"You can't do that in Zoom. You can play a video of somebody doing stuff, but it's not the same as somebody literally experiencing the same struggle that you are... you can watch them do the experiment because it's right there in front of you."*

Several educators highlighted that compared to other online learning platforms, DVW laboratories provide experiences that most closely resemble physical lab environments. As one educator remarked: *"That's as close to being in a real lab as you could get."* This creates opportunities for students to learn not just from their own experiments but from observing peers' approaches and outcomes.

For computing education, where multiple solution paths often exist for programming problems, this provides valuable exposure to different algorithms and debugging strategies; in programming courses specifically, this approach could enable students to observe different debugging strategies in real time as peers work through identical coding challenges, making the typically private process of debugging visible and instructive. Engineering students could similarly benefit by observing different approaches to design challenges, creating a richer learning experience than isolated problem-solving. Engineering design courses could allow students to see multiple approaches to the same design problem, creating exposure to diverse methodologies before students solidify their own approaches. This mirrors professional engineering practice where knowledge sharing and observing multiple solutions often leads to successful and improved designs.

2) Technical Students as Co-Designers: Most of the interviewed professors identified the time-intensive and technically demanding process of building learning materials and environments in DVWs as a significant barrier to adoption. By involving students in the technical development process, educators can transform this challenge into an opportunity for mutual benefit. This approach creates educator-student collaboration rather than merely assigned tasks.

One educator observed how this provides visibility and leadership opportunities for students who might be overlooked in traditional classroom settings:*"Um what I love about it... there are students that are computer savvy. And they may not be recognized in traditional school. Whereas here it kind of matches their skill set. So they became the experts.. and helpers, and they kind of took on that role which we love to see, because again, it wasn't always the case. But you often found that there were kids that may be shy, maybe that didn't stand out.. and a lot of them weren't like sports kids or... acting or drama like. Their talent showed up here. That helped kind of um, I think.. give them a boost in most cases. It also give the teacher themselves an opportunity to kind of stand back."*

For computing education specifically, this strategy offers programming practice with contribution to their learning environment. As one professor noted: *"The old virtual worlds like Second Life have their own scripting language... but for building for Spatial or other web virtual world applications, you need to use Unity."*

This enables computing students to develop meaningful projects with lasting impact, unlike typical end-of-semester assignments destined for abandonment. Students could create virtual laboratory simulations as part of software engineering courses, while engineering students can apply CAD skills to develop interactive models or simulations. As "co-designers," they help create customized environments that meet course needs and objectives.

This approach creates dual benefits. Students gain valuable technical experience through purposeful tasks with lasting impact. Simultaneously, they produce sustainable learning resources that reduce development burden for instructors and enhance educational experiences for future student cohorts. The strategy is particularly well-suited to computing and engineering disciplines, creating a virtuous cycle of student engagement and educational resource development.

3) Structured Exploration as Educational Strategy: This approach balances free exploration with purposeful educational activity through environmental design that guides student progressive discovery while preserving their agency; rather than directing every student's action, educators create environments that encourage exploration with general instructions and educational focus. One professor articulated the importance of meaningful structure for exploration: *"I personally coming from the background that I have felt like constructivism has been really misrepresented... my interpretation of it is not to just send the students off and they go learn on their own. It's to establish a well-defined structure around them... a journey that they take."*

This balanced approach prevents unstructured exploration while addressing the steep learning curve that all professors identified as a significant barrier for the education in DVWs. One educator transformed orientation into a gamified scavenger hunt with progressive challenges (Fig.1). This implementation demonstrated thoughtful progression, creating guided discovery and helping students gain navigation skills through increasingly complex tasks rather than relying on either direct instruction or complete freedom. Through this structured approach, students discovered different areas of the virtual campus where their future coursework would take place, simultaneously developing essential navigation skills:*"This is kind of to help students learn how to walk in the system, but you come over. And it's a training walkway and they go sign to sign... find learning activity places... as they go along, it gets a little more sophisticated."*

When completing the scavenger hunt, students needed to report their progress to the professor at various checkpoints. This approach ensured assignment completion while simultaneously encouraging communication in the virtual environment. Since many professors noted that students new to DVWs rarely initiate interactions spontaneously, one educator would proactively approach students asking "how are you doing?" to establish communication norms and help students become comfortable engaging with others in the virtual space.

For computing and engineering students, this approach has direct application to problem-based learning. Virtual environments could be designed with embedded challenges that students discover through exploration, similar to how professional engineers and programmers encounter problems in existing systems. Computer networking courses could create network environments with embedded diagnostic challenges that students uncover during exploration, mirroring how network engineers troubleshoot issues in production environments. This strategy reflects professional practice where problem definition often emerges through investigation within defined parameters.

Fig. 1. Structured exploration through scavenger hunt

4) Progressive Access Control: This strategy prevents student procrastination by controlling content access based on sequential completion rather than providing all materials simultaneously at the beginning of the semester. One professor explained the research basis: *"I did a lot of study on online courses and one of the big errors that people make is going: "here's all your assignments, get them done by X time at the end of the semester." And what happens when you do that is the students don't do anything for 99% of the semester... and then they attempt to do everything in the last 2 to 3 days."*

Another professor highlighted procrastination as the biggest issue for their students: *"The biggest complaints I get from my students is that they wish they had started earlier, because as they got into it and they started building . There was so many things they wanted to do, and they ran out of time."*

The professor's implementation of DVWs was highly structured with progressive unlocking of content: *"Most of these would be grayed out except for what they had access to for the week. So we don't do a wide open... they have things they have to do with deadlines, week to week. And we only open what they need to do."*

This controlled access creates consistent daily student engagement patterns that prevents procrastination common in technical courses where work complexity is often underestimated by students until deadlines approach. For computing and engineering education, where sequential skill building is essential, this ensures students' consistent engagement throughout the semester and prevents the common pattern of last-minute programming or design project completion. Software development courses could implement progressive DVW module access that mirrors professional sprint structures, preventing students from attempting to complete entire projects in final days. Engineering design courses could similarly implement staged access to design challenges, ensuring proper completion of analysis phases before moving to design and implemen-

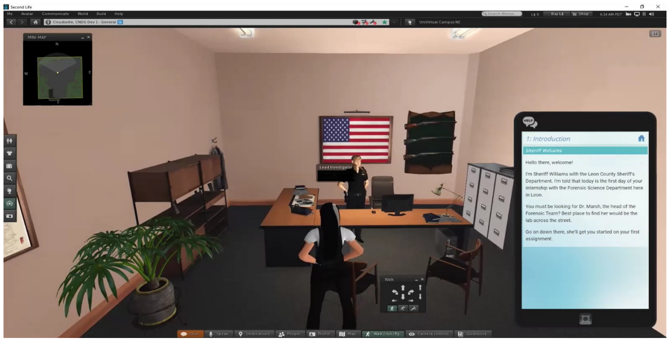

Fig. 2. Character-mediated instructions in a basic chemistry course

tation. This approach not only improves learning outcomes but also better prepares students for professional environments where work is typically structured in progressive stages rather than single deadlines.

C. Social Learning & Community Strategies

1) Character-Mediated Instruction: This method delivers instructional content through interactions with in-world non-player characters (NPCs) instead of direct educator instructions, while leveraging role-playing as a significant advantage of DVWs. Technical information and tasks are conveyed through contextually appropriate characters, creating situations where students assume complementary professional roles within the simulations. In the chemistry course built around the real murder case investigation, students took on the role of investigator interns receiving course assignments from a virtual sheriff character (Fig.2):*"We have NPCs. But we have a sheriff's deputy that they have to go talk to... as an investigator intern. Sheriff gives them assignments to go and collect evidence."*

This student role assignment creates purpose, context for learning activities, and engagement effects:*"It's not flat. They gotta go talk to the sheriff; and the sheriff's gonna tell them there's been a murder. They gotta get going. They gotta go get their evidence kit and get out to the murder scene... chop chop... Let's go."*

When interacting with contextual characters displaying human-like behaviors, students experience both narrative continuity and procedural realism, as they must follow professional protocols to progress through the learning sequence. Another important function of instructional NPCs is creating artificial co-presence. As several professors have indicated, DVWs can be a very lonely experience, particularly in asynchronous classes where students attend at different times. By populating these virtual spaces with NPCs, students can feel a sense of social presence, reducing feelings of loneliness during their learning activities.

For computing and engineering education, this approach could embed instruction within authentic workplace interactions where requirements come from clients, managers, or other stakeholders rather than directly from instructors. This helps students understand the diverse roles and communication patterns within these disciplines. Software requirements engineering courses could use virtual stakeholder consultations where students must gather specifications from character-based clients with varying communication styles and priorities. As AI agent technology advances, character-mediated instruction shows potential to become a more sophisticated and essential component of DVW education.

2) Multi-University Collaborative Environments: Most of the interviewed professors highlighted collaborative sharing and reuse of digital learning assets as another approach to lightening the implementation burden of DVWs. The collaborative nature of DVWs extends beyond resource sharing to include educational excursions across institutional boundaries. Educators reported conducting virtual field trips to colleagues' teaching environments, offering students exposure to diverse learning spaces and pedagogical approaches without creating these environments themselves. As one professor explained: *"We take students to visit other campuses and see what they're doing... it's like having unlimited field trips without any transportation costs."*

These cross-institutional visits help students engagement opportunities through environmental variety. One professor highlighted the engagement benefits: *"When students visit a new environment, their attention immediately spikes. They start asking questions about things they wouldn't have thought about in our familiar space."* Another noted the pedagogical advantages: *"Seeing how biology concepts are taught differently at another university gives students multiple perspectives on the same material."*

This shared environment practice offers multiple advantages beyond simply eliminating the need to create materials from scratch. It facilitates a community of practice, enables cross-disciplinary insights, and standardizes quality across institutions, while creating cross-institutional learning spaces where students interact with peers from different universities without administrative barriers. It also creates a dynamic educational ecosystem where both content and experiences are exchanged across institutional boundaries.

One professor described the natural interactions that emerge: *"Everybody has their banner as to who they are and where they're from, they realize there are kids there that are not from our university and a lot of times they'll go and interact with those people... just like who are you and what are you doing."*

Another noted the educational diversity: *"So they actually use the astrophysics labs for their majors course in Second Life. And of course ours is a non-majors course, so they talk to each other... interacting there with other campuses, which is something you wouldn't normally get in a different system."*

For computing and engineering education specifically, these virtual excursions expose students to varied technical implementations and disciplinary applications that broaden their perspective beyond a single institutional approach.

V. DISCUSSION & CONCLUSION

Our findings extend the current understanding of DVW pedagogical approaches by revealing how experienced educators have refined teaching strategies that can be adapted for computing and engineering education. Rather than simply transferring traditional teaching methods to virtual spaces, these approaches intentionally leverage the unique spatial and interactive affordances of immersive environments to address challenges common in these fields.

Experiential learning strategies transform abstract concepts into tangible student experiences, addressing a fundamental challenge in computing and engineering education. As Slezak [29] argues, students develop robust mental models through direct interaction with systems rather than through abstract descriptions. Our findings demonstrate how virtual environments enable experiential learning for concepts that would be impractical in physical settings. Scenario-based learning with high-stakes consequences creates the "emotional reinforcement" that Kolb [30] identifies as critical for knowledge retention, while mystery-based laboratory design positions students as active investigators rather than passive recipients of information.

Another method facilitating experiential learning in DVWs is scale manipulation, which facilitates embodied learning by integrating physical experiences through avatars with conceptual understanding beyond conventional perception limitations. This virtual embodiment provides students with intuitive knowledge that complements theoretical learning, particularly valuable for concepts involving complex spatial relationships or structures that benefit from spatial visualization.

Within the active learning domain, spatial co-presence learning emerges as particularly valuable for virtual environments. This approach builds upon Vygotsky's [31] social constructivism by facilitating the "legitimate peripheral participation" that Lave and Wenger [32] identify as central to communities of practice. By enabling student co-presence and observing and following peers' problem-solving approaches in real-time, this strategy helps transfer both explicit and implicit knowledge that would remain invisible in other online environments.

Engaging engineering and computing students as co-designers reframes the development burden into an educational opportunity with dual benefits. These students apply technical skills to meaningful projects with lasting impact, unlike typical assignments with limited shelf life. This creates a beneficial cycle where current students gain valuable experience while producing sustainable learning resources for future cohorts, directly addressing the significant development time required for creating learning environments in DVWs.

Progressive access control addresses the common challenge of student procrastination in technical courses, where work complexity is often underestimated until deadlines approach. This approach better prepares students for professional environments where work typically progresses through staged milestones rather than single deadlines. Similarly, structured exploration strategies address the initial learning curve through scaffolded orientation activities, helping students acquire basic DVW skills while becoming familiar with course educational spaces.

Social learning strategies, particularly character-mediated instruction and multi-university collaborations, create collaborative contexts that help students understand the social dimensions of technical work. Character-mediated instruction embeds learning activities within interactions with in-world characters, where students assume professional roles and receive contextual guidance. Together with multi-university collaborations, these strategies address the gap between academic preparation and professional practice in the computing and engineering fields.

Multi-university collaborative environments facilitate connections among educators worldwide, enabling resource sharing and cross-institutional learning opportunities without typical administrative barriers. This collaboration helps educators overcome content development challenges by distributing the workload across institutions while exposing students to diverse perspectives. As one professor noted: *" these virtual collaborations create "interactions with other campuses which is something you wouldn't normally get in a different system."*

Though our findings align with and extend established learning theories, additional quantitative studies measuring learning outcomes across different DVW teaching approaches would provide valuable complementary evidence. Future research might explore how these strategies perform across different student populations and institutional contexts.

The teaching strategies documented in this research represent successful educational approaches that help bridge the gap between academic preparation and the evolving demands of computing and engineering practice. By implementing these strategies, educators new to DVWs can use immersive environments to transform abstract concepts into students' engaging experiences, preparing students to apply technical principles creatively and collaboratively in addressing real-world challenges.

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