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Empowering Water Engineers to Develop XR Learning Applications with the WATERLINE Project †

Gareth Lewis [1,*], Matt B. Johns [1], Lydia S. Vamvakeridou-Lyroudia [2], Albert S. Chen [1], Slobodan Djordjević [1] and Dragan A. Savić [2]

[1] Centre for Water Systems, University of Exeter, Exeter EX1 2LU, UK; m.b.johns@exeter.ac.uk (M.B.J.); a.s.chen@exeter.ac.uk (A.S.C.); s.djordjevic@exeter.ac.uk (S.D.)

[2] KWR Water Research Institute, 3433 PE Nieuwegein, The Netherlands; lydia.vamvakeridou-lyroudia@kwrwater.nl (L.S.V.-L.); dragan.savic@kwrwater.nl (D.A.S.)

* Correspondence: g.lewis2@exeter.ac.uk

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Abstract: The over-arching goal of the WATERLINE project is the creation of a European Digital Water Higher Education Institution (HEI) Alliance, with a core part of this goal being the development and delivery of meaningful water engineering education through extended reality technology, allowing students to engage with virtualised water engineering models, such as flume tanks and water distribution networks in a manner that will promote engaged deep learning. To realise this goal, researchers need to engage with pedagogic, creative, and technical considerations to ensure that water engineering students are presented with engaging applications that provide the "right" knowledge and provide experiences where deep and memorable learning can take place.

Keywords: VR; digital learning; water engineering

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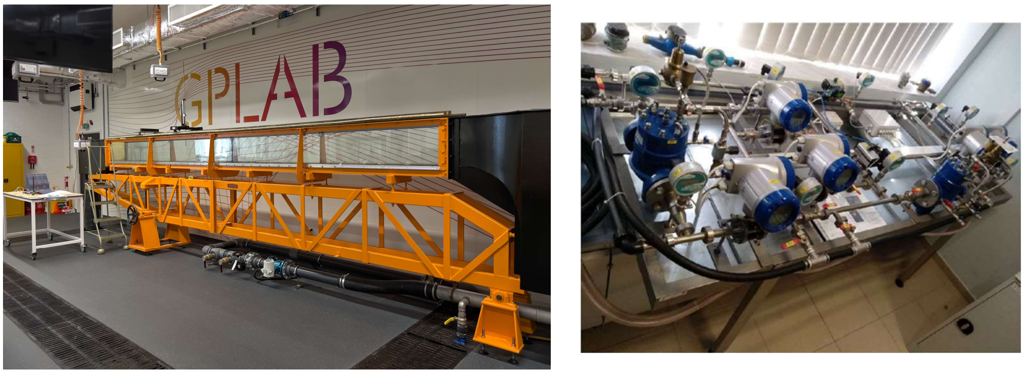
1. Introduction

The goal of the WATERLINE project [1] is to create a European Digital Water Higher Education Institution (HEI) Alliance, based on the quadruple helix model of innovation, leading to the development of the Alliance's research, educational and entrepreneurship capacities. A considerable component of this project is the creation of a set of learning artefacts that leverage AR and VR (collectively XR) technologies to facilitate the group and remote teaching of water engineering topics that often require access to large and/or unwieldy equipment, e.g., flume tanks, water distribution networks and so on.

Much of the need for this project came from the experiences of the project partners during the COVID-19 lockdowns, with traditionally in-person-delivered material being refactored and presented through on-line and video methods. Whilst these forms of presentation do deliver learning materials, Franklin's quote of "tell me and I forget, teach me and I may remember, involve me and I learn", is never far away, as well as Biggs [2] notion of "deep learning". Whilst water engineering materials have been taught through student engagement approaches, with physical experiments and demonstration, historically, it has been extremely difficult, if not impossible to share interactive flume tank and water distribution network material, see Figure 1, with remote students.

However, XR techniques now provide a potential solution to these issues through the creation of learning materials that virtualise large, and potentially complex, physical systems and allow students to engage with learning materials at their own pace. Of course, this process is a not a simple "build it and they will come"-type solution and careful consideration needs to be given to how meaningful experiences can be built for water engineering students that meet both academic needs and student needs.



(**a**) (**b**)

Figure 1. University of Exeter teaching water flume (**a**), and MCAST water distribution network (**b**).

2. Method

Part of the University of Exeter's role within the project is the provision of technology transformation for the learning establishments in the project consortium, with this paper detailing that role from three perspectives: pedagogy (what is to be taught), user experience (how the users interact with the learning applications) and technology (the underlying hardware and software stacks that power the learning applications).

Whilst it is tempting, and common practice, to think of these three perspectives as a design–build–test style process, the development of interactive media is often far more iterative, or incremental, in nature. However, it is not enough to simply describe the process as, say, agile [3] rather than just procedural, or waterfall. Instead, we have developed an approach this is geared around the following underlying pillars.

2.1. Incremental Development

Whilst it is tempting, and common practice, to think of these three perspectives as approaches to development: waterfall and agile (or incremental) development, for our work, incremental development geared around iterations of plan-do-test-review gives us the opportunity to undertake user-focused experimental development. The advantage of this approach is that we obtain early feedback that can be used to quickly address issues with development going in the wrong direction. The challenge with this approach is that it relies on managing user expectations as users are asked to test and evaluate early-stage work, though expectations are usually managed with paper-based prototypes.

2.2. Multi-Stakeholder Design Thinking

Design thinking [4] provides an incredibly useful set of techniques for exploring both "problem" and "solution" spaces and helps develop better overall solutions through user engagement. However, developing learning applications provides at least two users: academic content creators and students as receivers of content. Experience has shown that students typically do not know what they need to know, and academics do not always know what students want.

2.3. Sandbox and Narrative Design

We have borrowed these terms from the game development and game design document (GDD). Typically, a game comprises a sandbox (underlying systematic world model) and a narrative that drives the player through that game world.

Our water engineering learning applications are similar, in that they have an underlying systematic water model, e.g., EPANET [5], and a "learning" narrative that drives the user through the application.

Building this design document allows us to see what the "grand plan" of each application is. Moreover, maintaining this document to reflect the results of user testing gives us a "living document" such that we can not only see what the current state of the application design is but also see the decisions that have brought us to this point.

2.4. User Testing

Testing is a core aspect of both incremental development and design thinking. Currently, we are engaging with qualitative approaches through structured usability testing [6], in which we walk users through paper-based prototypes and encourage them to "think aloud" about their engagement. This provides us with valuable feedback and the paper-based nature of the prototypes allows their functionality to be quickly refined with Post-it notes and hand-written updates.

2.5. Paper-Based Prototyping

Paper-based prototyping gives us an environment where we can experiment with content development and delivery without needing to engage with time-consuming technical R&D. Users can be walked through a Post-it note and cardboard representation of learning content and asked to verbalise their thoughts, allowing for issues to quickly be raised and potentially addressed through just-in-time alterations to the current content.

Whilst it is very clear that we are ultimately developing XR applications and we would assume that users would struggle with seeing paper rather than VR, users are generally quick to reset their expectations and happy to provide critical feedback, not least once they see that their requests can be quickly iterated. This is something that we generally do not see as much with actual digital applications.

2.6. Technical Research and Development

Whilst the fundamental challenges with this project are design-centric, i.e., making learning applications that are engaging and teach the users, the key perceived challenges are with technical implementation. This is to be understood with technology projects, particularly when developers do not have a lot of experience with VR development.

To address this, we have a technical R&D aspect to development, such that the developers can spend time upskilling on the Unity and Unreal Engine technologies that they are using for their respective applications.

3. Results and Next Steps

To date, the application development partners have enthusiastically adopted the design pillars and produced initial design documentation through working with academic and student partners. This approach has allowed them to obtain a clear understanding of who their users are (both academic content providers and consumers) and start to become engaged with the nature of the problems that they are dealing with. Having a clearly defined technical research pillar has also allowed them to spend some time dealing with the technology concerned and has allayed their implementation fears.

The design documents have allowed the partners to have clear and unambiguous descriptions of what they are doing which are shared between the partners with a common set of design terms. Likewise, technical solutions are being shared between partners to build more development confidence within the project.

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