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***Abstract*— eXtended Reality (XR), an umbrella term referring to augmented, virtual and mixed reality, is a rapidly evolving technology that has the potential to reshape various processes and activities within the educational domain. Over the last five years there has been a significant growing interest in the technology's use by both educators and researchers exploring the applicability for active learning and student engagement. However, an essential consideration for its use in education is engagement with the end users during the design processes. For that reason, a hackathon was organised by Wageningen University to engage with students in order to design and develop XR applications for data science education. Hackathons have become more commonplace over the last 10 years, in particular due to their success for creating innovation and enhancing engagement with students. In this research, the results of the hackathon are presented along with the challenges and opportunities associated with the implementation of such pedagogical activities. Our findings indicate that XR-based gamification of education has potential valid application for improving the way elements of the data science pipeline are taught, and that a student-led design process demonstrated a preference for the use of virtual reality over augmented reality. The results reveal that the usefulness of XR to foster learning is evaluated positively with a mean score of M=5.82 and SD=0.98 on a 7-point Likert-scale.**

Keywords—Extended Reality; Virtual Reality; Hackathon; Education

I. Introduction

Within data science education, students experience four layers of learning that together form the Data Science Pipeline. Namely, (i) Data Sourcing, covering big data, variety in data (i.e., structured/unstructured) and data collection methodologies; (ii) Data Cleaning and Manipulation, involving governance, storage, removal of errors, fixing artefacts and feature extraction; (iii) Data Analysis, encompassing the exploration processes, descriptive statistics, machine/deep learning and generation of results; and (iv) Data Visualisation and Storytelling, involving presentation of the findings in a meaningful and communicative manner. These stages are commonplace in a diverse range of data science education material [1] and the pipeline can be considered as comparable to a factory production line. These layers take the students on a journey from raw data collection (input) to establishing new understanding and insight (output) in their own specific field of study.

However, some specific components of the Data Science Pipeline are abstract in nature (e.g., multidimensional data) and because of this, students often struggle to understand form and function [2], how processes impact on each other, and that the layers build on one another. This challenge of understanding form and function is not just unique to the data science field but also apparent in other education domains [2]. Not understanding one layer would, thus, make it challenging to understand the subsequent layers.

To solve educational challenges, specifically when integrating new digital tools into the classroom, a bottom-up approach may create more effective designs, as the innovation is led by the end user: the student. This because the solutions being designed are directly addressing specific learner needs. To achieve a bottom-up designed XR solution, events such as hackathons (i.e., 'hack' 'marathon') have become more commonplace at universities. This is because hackathons have been identified as key for the promotion of novel ideas, with Rys et al. outlining their benefits for sparking invention [3] and, as Heller et al. discuss there is a 'close connection between hackathons and the production of innovative ideas' [4]. The process is often perceived as an evolution of other types of brainstorming sessions. Additionally, such events also open up the possibilities to create awareness of new technologies to a much broader audience within higher education; sparking conversation on the future of learning, whilst putting the stakeholders (namely, the students) at the centre of the conversation.

Therefore, by conducting a hackathon for co-designing XR-based tools for data science education, this investigation aims to solve two major aforementioned problems: 1) students do not always understand how form (data concepts) and function (the data processes) go together, and 2) that the processes are dynamic. This interlinked nature of the subject, and students being able to understand how form and function are combined, can make Data Science Pipeline a challenge to teach. Also, dynamic processes are often taught using static imagery and diagrams in textbooks and lecture slides. Therefore, in the paper we present the Data Factory hackathon, in which the participants designed XR-based software applications using game engine technology that are dynamic and can be used in different data-focused courses.

The remainder of this paper is as follows. Section 2 discusses existing, related work, Section 3 outlines the methodology of the hackathon workshops and section 4 displays the results. The paper is concluded in Section 5.

II. Background

Across a broad spectrum of subjects, XR-based technologies are proven to have a positive impact for students' learning in comparison to traditional practices, typically when simulation or hands-on learning can improve the pedagogical process. Examples include the investigation by Zare-Badiki et al. involving the use of VR for teaching medical students about psychosis [5], Dobrova et al. who demonstrate the effective use of VR for language education [6] and Hung et al. who make use of AR for material-based education [7]; further, in our related work, we demonstrate the benefits of using VR for biochemistry education [2]. In short, there is a growing volume of research concerning the integration of different XR-driven sub-technologies into a spectrum of educational subjects at various levels of the curriculum and education pipeline; from primary school [8] to university level [9].

Often these applications are developed using game engine technologies (i.e., Unreal or Unity) and involve a customisable immersive application, whereby the inclusion of the third dimension enables students to better visualise a complex process or allow them to experience a setting they would not be able to in the real world. This is due to several reasons: 1) the inclusion of a third dimension supports the communication of multidimensional subject material - A specific example could include the notion of multidimensional data, which is an important concept to understand for the data pre-processing stage. This is built upon when conducting more technical processes, such as machine learning; 2) immersive experiences can create a surprise reaction in learners, which in result improves memory retention and 3) multiple studies have demonstrated a measurable increase in engagement and stimulation when XR is included. Examples of which are discussed in the following sub-section.

A. *XR for Education*

Based on a systematic review of empirical studies on the use of VR-based serious games by Checa et al. [10], findings indicate (through the review of 31 articles) that the added pedagogical value of the technology's integration was apparent on all educational levels. Further, the applicability of such games was mainly focused on external use with healthcare education topics. Another review by Dong et al. [11] evaluate the teaching cycles, subject categories and differing education levels, with the authors concluding by providing a quantitative evaluation of the impact of both VR and AR; whereby, the technologies are demonstrated to be able to reach up to 0.723 and 0.951 effectiveness respectively [11]. Alnagrat et al. [12] conduct a review on the current trends of XR in teaching, investigating articles from five digital libraries. Their article outlines that XR technology has the potential to boost confidence and multi-sensory learning as well as promoting self-study initiatives. Yet, the authors identify several limitations, namely relating the ergonomic challenges and how errors affecting the game play can be considered an issue for the students. Therefore, consultation with the end-users, namely the student stakeholders, should be paramount for a teaching-focused application. One potential metric for engaging directly with the students is by means of the hackathon process. In the following section, existing works on the use of XR hackathons to engage students are outlined.

B. *XR and Hackathons*

There remain multiple examples of academic institutions around the globe that have organised XR days and hackathons with focus on the gamification of various educational content. The outcome of these edutainment organisations is research development and study of the impact of these serious games in 3D educational environments. Specific examples include HackerEarth [13], which invited participants (namely, brand creators, mentors, students, technology enthusiasts) to develop innovative XR applications. The multidisciplinary backgrounds and competencies of the participants in combination with the collaborative approach of the hackathon resulted in fruitful brainstorming sessions and innovative concepts. Another example includes the VR hackathon organised at Goethe institute by in 2019. During this event, participants were given the challenge of designing an application for use within the language learning domain [14]. In a further study by Skrupskaya et al. [15], the authors outline the importance of structure in XR-based hackathons to allow for design thinking and support the student participants. Specifically, the process should cater for empathising (observation and engagement), define (provision of a problem or challenge), ideate (collective reflection and idea generation), prototype (developing a concept) and finally testing (receiving feedback on the application).

The results of the aforementioned articles provide information regarding the implemented frameworks of design cycle thinking and a customer-centred focus in design process and interdisciplinary ideation phases. In the following section the methodological process for the Data Factory hackathon is outlined, whereby we adhere specifically to the five-stage structure outlined by Skrupskaya et al. [15].

III. Methodology

In this section the design characteristics of the event are outlined.

A. *Hackathon Process and Activities*

Following the investigation into related works on XR-focused hackathons outlined in the background section, the event (titled The Data Factory) adhered to a co-creation process, bringing people together to design concepts for a specific topic of focus. Crucial to a hackathon process is the identification of a specific research goal, which must be established prior to fieldwork [3]. At the Data Factory, the goal (and topic focus) was the design of a serious XR-based game for data science education. Data science was chosen due to the underlying four challenges for data science education outlined in Section 1.

The Data Factory event took place at the Wageningen University on 23rd and 30th November 2023. As Heller et al. identify in their literature review on general hackathon design [4], there are typically two approaches for recruiting participants: open and selective. We adopted the open-based methodology, with the event openly promoted to students at BSc, MSc, and PhD level from any subject background but with an interest in data science. The initial event limit was set to 30 students, with 29 signing up and a total attendance of 21; none of whom had any prior experience of XR-based education. The advantage of open recruitment is that it generates a higher diversity range, and this is likely to result in effective outcomes. Specifically, Groen et al., [16] outline how diversity (namely, students with different skill sets and scientific backgrounds) can facilitate the division of tasks, thus breaking the overall project into smaller building blocks; and as Paganini et al. [17] outline, the openness may also support the establishment of a gender balance.

The 21 students were randomly divided into 5 teams and, on day one, the initial focus was on introducing participants to different XR hardware and software development tools, to allow for observation and engagement. As displayed in Figure 1, students were initially given the opportunity to test VR headsets (incl. the Quest 2, Quest 3 and HTC Vive Flow) and introduced to VR development software (incl. the Unity and Unreal game engines and Aryzon.World).

Figure 1. VR Hardware and Software Workshop

After the opening VR workshop, students had the opportunity for ideation (Figure 2), whereby the participants were provided with sticky notes and invited to individually propose ideas to their group. Each participant was then given 2 minutes to pitch their ideas to their groups in a round-robin format and then 10 minutes to decide on a final idea to pursue as a team in collective reflection. This was done in order to establish a collaborative atmosphere within the individual teams, which as Calco et al., discuss, can promote creativity and satisfaction [18]. The remainder of the day involved design thinking activities, providing the students with standard wireframe tools (incl. including storyboards and wireframes) to support their move away from the ideation to the creation and implementation processes.

Figure 2. VR Game Design Ideation

Between day one and day two, the students had seven days to work on their ideas (prototype development), with day two focusing on finalising demonstrations of prototypes and a pitch to a panel of judges (receiving feedback on their applications). As typically with a hackathon, different products or ideas are pitched to a panel. In this case, the expected outcome of the Data Factory event was a series of designs, concepts, and ideas for teaching complex processes of the data science pipeline, a sample of the output is presented in Section 4. Teams were not expected to develop a prototype, however four of the five did so. Each team was assessed on their work regarding the novelty, feasibility, creativity, link to data science and extra credit (implementation/TRL and realisation of idea etc.), with prizes handed out to the top three groups.

B. *Survey Process*

During the first day of the hackathon event, students were surveyed in a quantitative (on a 7-point Likert scale) and qualitative manner, using an online questionnaire. The topics of interest were explored with validated questionnaires as extracted from the literature. The topics were: (1) current method(s) used for learning, (2) used learning strategies, (3) level of confidence using XR for learning purposes, (4) prior experiences with XR learning tools, (5) opinion of the usefulness and ease-of-use of XR learning tools, (6) motivational drivers of XR learning, and (7) the expected overall potential benefits of XR.

As Rys et al. [3] discuss, despite their increasing application, hackathons are relatively still undiscovered and unexplained methods; thus, in this investigation the researchers considered that it would be beneficial to include feedback on the hackathon process from the students in the form of open questions. Post hackathon (at the end of day two), a survey was conducted regarding the general experience and also providing opportunity for the students to further reflect on the use of XR for teaching. For these purposes, the tool Slido, which has been actively used in other academic class studies [19], was used to create open-based interaction questions: 1) What did you think of the hackathon? and 2) Did the hackathon encourage you to think further about XR for teaching? (*Yes/No and Why*). The results of the quantitative and qualitative data are presented in section 4.

IV. Results

In this section, the student designs are presented along with the findings from the survey process.

A. *Outputs and Designs*

On immediate inspection, the outputs indicate that the participants predominantly adhered to use of the technologies demonstrated during the opening workshop on day one. All participants used Unity game engine for the development processes, with one team also integrating Aryzon.World into the development process. Figure 3 displays a visualisation of the output created by three of the teams.

The displayed solutions in Figure 3 were all intended for use with the Meta Quest 2 and 3, with each requiring hand-based interactions by means of the controllers. The three solutions presented were developed for different stages of the data science pipeline. For example, Group 1 focused on teaching principal component analysis in VR through platform Aryzon.World (Figure 3A1-A2), linked to the Data Analysis stage. Group 2 focused on completing farming activities (Figure 3B1-B2) that link to data cleaning and manipulation (stage 2). For example, removing weeds (data outliers) from your crops (datasets). Team 3 took a more holistic approach, catering for the integration of videos in a VR environment (Figure 3C1-C2) then putting 'what you learn into practice' by means of a series of interactive experiences, producing a solution that crossed the Data Manipulation and Data Visualisation stages.

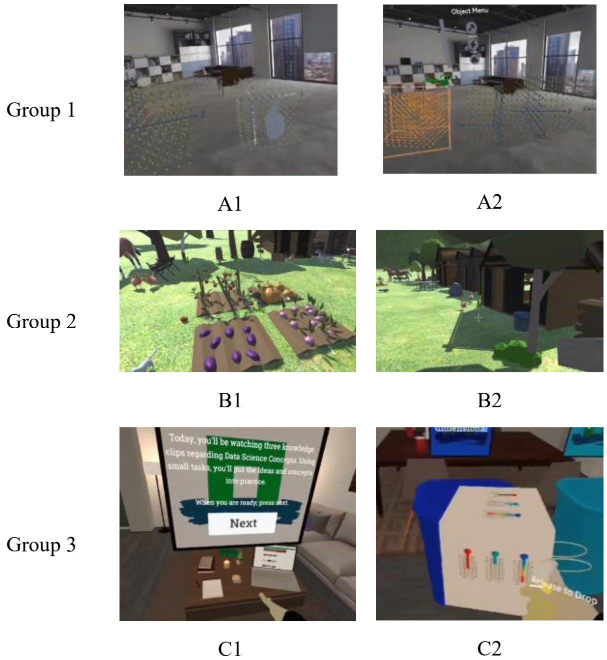

Figure 3. (A1-2) Principal Component Analysis plots in VR, (B1-2) Farming Simulator in VR, (C1-2) Data science concepts experience in VR.

B. Survey Feedback Overview

The survey response rate was mixed, with some questions receiving a higher completion rate than others. The trend indicated that overall, the survey completion declined as the hackathon progressed (as further discussed in sub-section *D*). From the 21 attendees, 18 started to complete the pre-hackathon survey. The majority of students were MSc level (*n=14*), with BSc (*n=1*), PhD (*n=2*) and other (*n=1*).

Table 1. Open Questions Pre Hackathon – Benefits

Response type	Response
Open Response	-*'3D environment provides depth and interactivity with the objects around'*; -*'Mitigate distractions and make learning an immersive experience'*; -*'More realistic visualization to the learners'*; -*'Can make it more fun, help motivate. Also some things might be more clear when viewed in a 3d environment, like certain graphs'*; -*'Because you may get a more immersive experience which may mean you can remember things better'*;

Table 2. Open Questions Pre Hackathon – Comfort*

Response type	Response
Concerns	-*'Comfortability of the headsets and weight'*; -*'The headset design, such as weight distribution, and ventilation e.g. adjustable straps, lightweight materials'*; -*'Form factor, weight, facial interface material, prescription (built-in)'*; -*'Weight off headset. Screen brightness. Loudness of noise'*;

After signing in for the event, students were given the opportunity to respond to open-text questions. This provided them with the prospect to reflect on what aspects they would consider beneficial for an education focused XR application prior to starting their design process. Table 1 provides a sample of the open responses to the question '*why do you think a 3D environment that you can explore would be helpful?*' with Table 2 providing and overview of responses to '*how comfortable do you think you would be during an extended reality study session – and what factors would contribute to this?*'. Both questions received a response of rate of 72% (*n=13*). The intention was to provide a student-led open reflection for other academics to refer back to when designing future XR-based applications for education. The objective was also to demonstrate the students' prior preconceived expectations of XR and their use, gained from general media outlets. In both Table 1 and Table 2 responses have been adjusted to account for spelling mistakes.

Apparent in Table 1 is that the students expect a broad range of benefits from the use of XR. For example, that interactivity will increase, distractions may decrease or that information retention would improve.

Regarding the consideration of comfort in Table 2, 61% (*n=8*) referenced weight as a factor that would be important for them individually when considering prolonged use of XR equipment. Other comments relate to the playability of the actual applications with one student surmising that '*some things might be more clear when viewed in a 3d environment, like certain graphs*'. The reference to application quality is a notable consideration and is referred to as the convenience of the application; whereby the response to a VR experience deteriorates (or the user feels a level of nausea) when playing if the application lacks a certain level of realism or when there are frequent errors in play. This notion has also been recognised in related works on VR [20] for prolonged use.

What is evident throughout the open-text feedback, is that the majority of the participants consider XR to be focused on VR-based hardware, with *n=0* responses relating to either AR or MR in the text. This finding emphasises the importance of our early Data Factory activities where students were initially given time to experience use of different XR-based tools and technologies. Thus, one clear finding from our event is that future hackathons should be encouraged to lead with introduction to technology sessions.

C. Survey Feedback Analysis

The majority of participating students indicate that they had no prior experience with the hackathon approach (*n=9* no, *n=1* yes). This was also displayed in the fact that most students indicated that they were very excited to participate in the hackathon (*M=6.33; SD=.68*) but seemed to be less nervous about the event (*M=3.56; SD=1.68*).

When it comes to existing devices, used in their learning trajectory, the majority of students indicated to make use of their computer / laptop (17 out of 21), followed by the use of pencil and paper (14 out of 21).

To evaluate students self-regulating learning strategies, we used an adapted version of the self-regulating strategies questionnaire developed by [21]. According to Toering et al.

[21], learning strategies can be assigned to the subgroups of planning, self-monitoring, effort, reflection, and self-efficacy. Interestingly, the results show that students perceive the effort and the associated reflection processes as more important that the other self-regulating strategies (Figure 4).

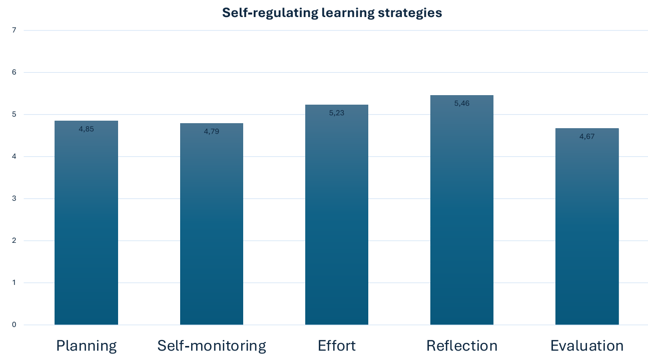

Figure 4. VR Game Design Ideation

When it comes to the use of XR in the learning context the perceived usefulness and the ease of use are pivotal constructs, driving the technology acceptance. We, therefore, asked participants to evaluate both dimensions of the Technology Acceptance Model (TAM). Interestingly, the results reveal that the usefulness of XR to foster learning is evaluated positively with a mean score of M=5.82; SD=.98 on a 7-point Likert-scale, while the ease-of-use is evaluated slightly lower (M=5.50; SD=1.18).

The perceived learning experience is also a driver for satisfaction with or within a learning experience [22]. We, therefore, asked participants to indicate the perceived effects of XR on learning, the perceived ease of use, and the satisfaction with learning. To further explore the perceived distance between students and XR technology, the transactional distance questionnaire [23] [24] has been used. The results display that students feel in general confident in using XR applications in their learning environment (M=4.85; SD=1.20), though they have never used XR tools for learning purposes before. Also, students indicate to be satisfied, confident and pleasant when using XR. An important finding is again the display of the students' positive opinion regarding XR in the learning environment.

Table 3. Open Questions Post Hackathon*

Response type	Response
Open Response	-*'Yeah sure, VR could make the teaching experience more immerse and simplify it apart from its complex structure';* -*'Yes, because I first did not think about it at all. At first I did not see the added value of teaching new things in XR, but now I have changed my mind. I now think that it is a fun and interactive way to learn new concepts.';* -*'Yes, because it seems like XR would appeal to a lot of people';*
Future Directions	-*'Real examples on what people have done in the specific topic of the hackathon.';* -*'More female representation from industry and experts.';*

*questions - responses to both are combined

Table 3 details the responses to the open text questions collected post-hackathon using Slido. We include the responses for others to build on when designing and planning for a hackathon.

D. *Discusssion*

It is notable that survey response rates declined as the hackathon progressed, likely due to the event's complex and competitive nature, making it challenging for participants to focus on completing surveys [3]. Hence, the survey responses only capture a partial opinion of students participating. Despite, valuable insights emerged from both quantitative and qualitative data. Specifically, XR elements integrated into the hackathon were positively rated for enhancing learning progress. Students particularly valued the learning strategies of '*effort*' and '*reflection'*, both of which are integral to XR applications. This suggests that XR can be a beneficial tool for students in their learning trajectory, helping them particularly in the learning process and reflection processes. Additionally, students expressed satisfaction with the usefulness of XR, although the ease-of-use remains an area for improvement, indicating XR's early stage of development in learning contexts. Overall, the findings suggest that students perceive merits in utilizing XR technologies.

V. Conclusion and Future Work

Existing research demonstrates that by incorporating the technology along-side textbooks, lecture slides, videos, graphics, etc., XR provides the opportunity for students to interact and experience. Thus, potentially offering a new metric for data science learning. As recognised in this paper, what is needed are student-centric designs for suitable XR-based applications that meet their specific learning needs. As such, this paper documents the findings from the Data Factory hackathon, whereby students were given the opportunity to design XR-based applications for data science education. Despite encouraging elements, such as the event gaining positive feedback from the participants, the design / prototyping of innovative VR-based applications and survey-based insights, there are some notable points for future considerations. For example, a clear element would be a better demonstration of a wider range of software and hardware at the start of the event. However, there must be a balance to make sure the students are not overwhelmed; particularly those with no / little previous XR experience.

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