Comparison of 2D Virtual Learning Environments with Classic Video Conferencing Systems and face-to-face Classroom Teaching for Tertiary Education

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***Abstract*— This study builds un our previous research examining various virtual learning environments for tertiary education, including a comparative analysis with traditional classroom teaching. The main focus was to evaluate the suitability of a 2D Virtual Learning Environment (VLE) for tertiary education utilizing, the desktop-based 2D immersive environment gather.town, and to contrast it with conventional video conferencing systems. The results of the previous studies indicate that the desktop-based 2D environment is an appropriate learning environment for the tertiary sector. In addition, an analysis of exam grades showed that students demonstrated superior performance with gather.town compared to classic video conferencing systems. This study builds on the previous research by conducting a comprehensive analysis of the learning environments, including a comparison with traditional face-to-face teaching. It can be confirmed that there is a significantly higher level of immersion in the 2D desktop environment, gather.town, in comparison to the classical video conferencing tool, zoom. However, the effects of significantly higher learning engagement and better grades, as observed in comparison 2023, could not be confirmed. Further studies are planned for the winter term 2024/25, with the aim of obtaining results for the next level of immersion, achieved through the use of a 3D desktop environment.**

Keywords-Virtual Learning Environments; Online Teaching; Tertiary Education; 2D Desktop Environments; Zoom; gather.town; 3D Desktop Environment.

I. INTRODUCTION

This paper presents the results of a long-term study initiated in 2022, to analyse the suitability and differences of virtual learning environments (VLEs) for tertiary education and the latest findings in 2024 [1]. Following the discovery of the suitablitly of a 2D desktop environment for tertiary education [2], this was confirmed in further studies conducted within the same lectures of the Masters´s programme in Integrated Innovation Management at the Technical University of Applied Science Würzburg-Schweinfurt [3] [4]. Subsequent studies showed a clear and statistically significant distinction in terms of increased immersion, improved learning engagement, and superior academic performance when comparing the 2D desktop environment with the Zoom videoconferencing systems [2] [3]. This study is currently in the process of analysing data collected and partially published in 2024 [1], with the aim of completing a comparison of the 2D desktop environment gather.town [5], with the videoconferencing system Zoom [6] and face-to-face lectures held in a classroom setting. The complete schedule of previously analysed lectures and utilised assessment instruments, spanning the winter term of 2021/2022 and planned lectures incorporating 3D desktop environments, is illustrated in Figure 1. The comparative analysis presented in this publication is delineated with a frame.

The impetus for this study was the ongoing impact of the global pandemic caused by the SARS-CoV-2 virus and the considerable challenges posed by the implementation of public health measures and the subsequent lockdowns in education, particularly in higher education institutions [7] [8]. In consequence of the pandemic, universities and other educational institutions were compelled to transition entirely to online teaching and remote learning [9], primarily utilizing video conferencing software such as zoom, Microsoft Teams, and Google Meet [10] [11]. However, this transition has not been without difficulties. Students have expererienced difficulties, particularly in regard to interactivity, motivation, and academic performance, as a result of the lack of in-person engagement and the limitations of video conferencing technology [12] [13]. The term of “zoom fatigue” become established for this phenomenon and has already been addressed in numerous studies at universities [14] [15] [16]. In order to enhance the learning experience and create a more motivating and activating environment, this long-term study, which commenced in the winter term of 2021/22, employed the 2D desktop environment gather.town. The initial findings indicated a favorable compatibility between this avatar-based learning environment and the gather.town platform [2]. Subsequent assessments within the study substantiated the preference for gather.town over zoom, primarily due to its superior interactivity, comprehensive range of features, and motivational aspects. [3]. The objective of this study and subsequent research is to examine the distinctions between learning environments with the aim of enhancing online education in tertiary education, specifically in relation to seminars on management topics.

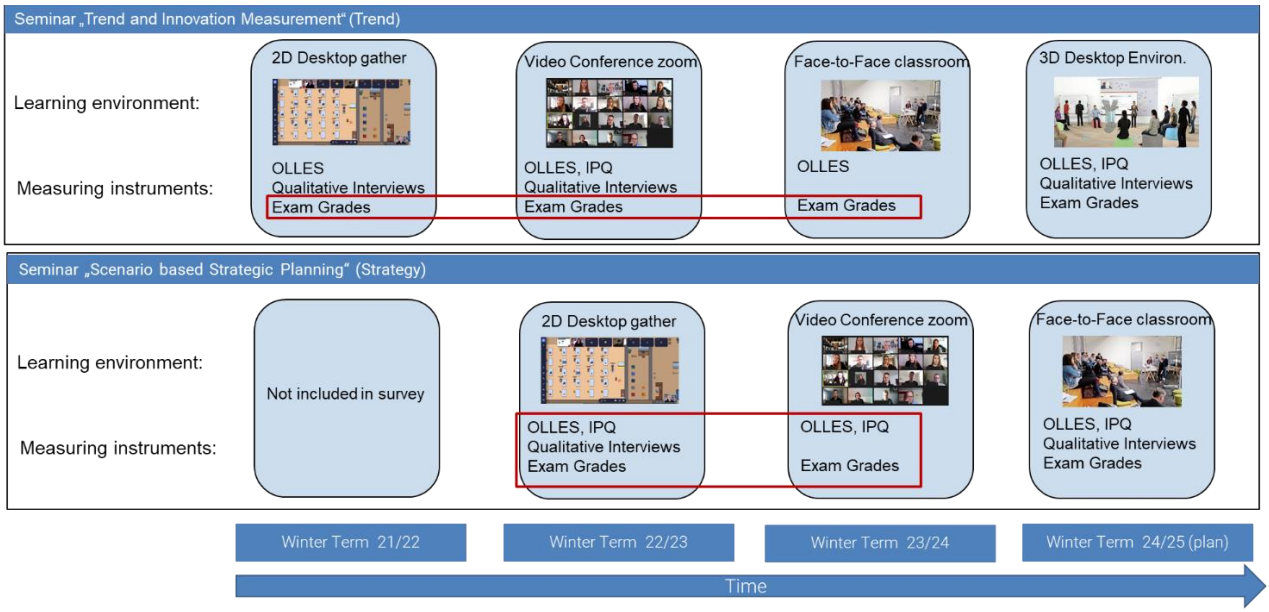

Figure 1. Overview of seminars, learning environments and measuring instruments for finished and planned studies in this long-time study.

In conclusion, the partially published results for the questionnaires and the exam grades for the seminar, entitled "Scenario-Based Strategic Planning" (subsequently referred to as "Strategy"), held during the winter term of 2022/23 will be presented alongside those of the winter term of 2023/24. Furthermore, the comparison of exam grades for the seminar “Trend and Innovation Measurement” (further on “Trend”) from the winter term of 2021/2022 to the winter term of 2023/2024 are included, as illustrated in Figure 1 with frames. Due to the analysis of related work done in the previous papers [1] [2] [3] [4], Section II just gives a short wrap up on related work and definitions. The learning environments gather.town and zoom will be described in Section III, as well as the measurement tools “Online Learning Environment Survey” (OLLES) for measuring ability to interact [17], and the “Igroup Presence Questionnaire” (IPQ) [18] for immersivity. Section IV summarises the results, which are then discussed with some limitations in Section V. Section VI concludes the paper with the main conclusions and future research.

II. Related Work and Definitions

Prior to providing a concise overview of related work, this section first defines the related Terms in Chapter A. This is done to ensure consistent conceptual definitions and prevent potential misunderstandings. Chapter B offers a brief look at the related work. For a more comprehensive analysis, we recommend referring to our previous publications [2] [3].

A. Definition of related terms

Before looking at related works, it makes sense to determine some basic definitions for terms of Virtual Reality (VR), immersion and Virtual Learning Environments (VLE). VR can be distinguished between immersive VR (I-VR) including additional devices like a head mounted display (HMD) and non-immersive VR on the screen of some end devices, also known as desktop VR (D-VR) [19] [20] [21] [22]. Di Natale [23], proposes a tripartition. He differentiates at the poles between non-immersive systems such as desktop VR (D-VR) and immersive systems such as HMD or specially designed rooms with projected walls (CAVE). In between, he places semi-immersive systems, such as AR or wide-field displays. It seems that the term of immersion started to become synonymous with “presence” [23]. Despite the strict separation between non-immersive and immersive VR, recent studies tend to consider immersion as a continuum, with highly immersive or high-end for I-VR and low immersive or low-end for desktop VR systems (D-VR) [24] [25] [26]. This is likely due to the fact that desktop VR systems are capable of facilitating a certain degree of immersion and spatial presence. VLE is a term that includes a wide range of systems like simple web pages, learning management systems like MOODLE but also three-dimensional learning environments like Second Life or OpenSim [27]. Reisoğlu [28], following Zuiker [29], defines the term "3D Virtual Learning Environment (3DVLE)" and describes it as platforms for virtual worlds with avatars as representatives and the ability to communicate via audio or text, such as Second Life or OpenSim. Other authors use the term „immersive 3D virtual world” or “immersive 3D virtual environment” for similar systems to describe computer based simulated environments, in which users are able to immerse themselves through avatars [30] [31]. We will follow the wording of “immersive 3D/2D virtual environment” to describe desktop VR with different levels of immersion. If 3D-like representations are used in the desktop environment, we assign them to an immersive 3D desktop environment and, in the case of a two-dimensional representation, to an immersive 2D desktop environment. Figure 2 shows an overview of the different virtual learning environments and their classification on the level of immersion as used in this and following papers.

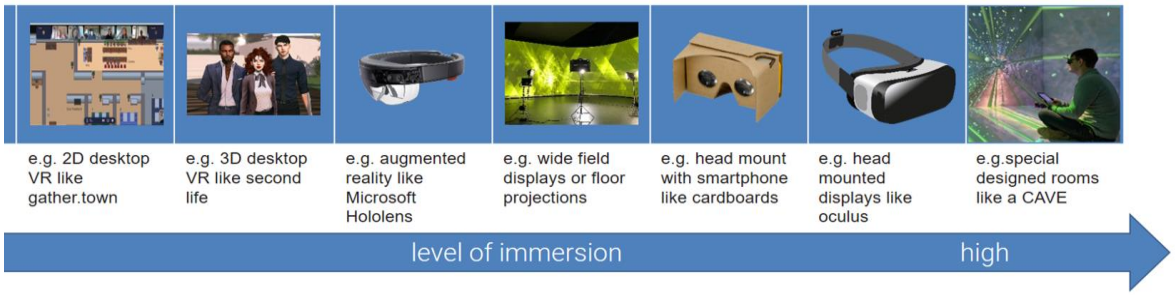

Figure 2. Overview of different virtual learning environments according to the level of immersion.

B. *Studies about VLE in education*

There are several studies on the impact of mainly immersive VR (I-VR) in higher education, especially before the global pandemic caused by the SARS-CoV-2 virus, as described in Introduction Section I. Chien et al. [32], stated that a VR environment increases motivation and critical thinking skills. Tepe [33], concluded that a VR environment increases performance and professional skill development. Additionally, other studies also showed several positive effects on academic success and motivation [34] [35]. In the field of higher education, a meta-study analysed studies on desktop-based virtual environments, games and simulations in particular. They concluded that these virtual tools could be effective in improving learning outcomes [36]. Akgün [37], concluded that there are numerous positive effects on students' abilities, including an increase in motivation and other positive contributions to learning. Despite these positive results, the study also determined that there are still technical and health problems to be solved. Moreover, a number of studies have been published on the subject of educational online learning, especially with Learning Management Systems (LMS) such as Moodle and Video Conference Systems, especially Zoom [38] [39] [40] [41] [42]. Also, many studies on the phenomenon of "Zoom fatigue" were published [43] [44] [45] [46] [47], which emphasizes the need for alternative online Learning Environments like low immersive Desktop Environments. Probably because of this need, several studies appeared with gather.town as one example for this kind of Virtual Environment. A review of 11 empirical studies conducted by Lo and Song [48], confirmed that users in gather.town exhibited greater engagement than those in other environments. Another finding of Lo's study was that there is still a dearth of research outside of computer science courses, and studies of longer duration are lacking [48]. In conclusion, there are several studies of desktop VR (D-VR) respectively VLE for specific topics, often related to computer science or medicine [49] [50] [51] [52]. These studies have explored various levels of immersion, yet a comprehensive evaluation of the suitability of 2D desktop learning environments for higher education remains lacking.

III. METHOD

In the following, we present the immersive learning environment gather.town (Chapter A) and the Video Conferencing System zoom (Chapter B), in which the courses took place. They also present the assessment instruments OLLES and IPQ (Chapter C).

A. *Immersive 2D environment gather.town*

The software gather.town [5], was employed as an immersive 2D environment. This is a web-based conferencing software that enables the creation of a complete virtual replica of the teaching facility. Within this virtual environment, users can move around using avatar representations and engage in interactions with each other and their environment, in a manner that closely resembles to the "real-life". Should the avatars traverse the virtual environment and subsequently encounter one another at a designated distance, the camera and microphone of the computers are automatically activated, thereby facilitating communication between the users. The graphical user interface is quite simple, and it does not require any special hardware or software to run on a variety of computers. In preparation, the entire real seminar facility was recreated in the gather.town environment and the following Virtual Environment settings and software features were used. The podium represents the classic teaching situation, as shown in Figure 3.

Figure 3. This is the podium. You can see a classic teaching situation in a shared space.

Within the gather.town learning environment, all students and the tutor are situated in one large room. The tutor assumes a position at the lectern, while the students take their seats at the tables. All students are able to see, hear and communicate with each other via camera and microphone. It is possible to share the screen to provide lecture slides or other content to all participants in the plenum area. In this way, the tutor can

utilise lecture slides in addition to a verbal execution of the learning topic, as they would be used in a real teaching situation. For further information on the aforementioned features, like “Workshop”, “Whiteboard”, “Break Rooms” with games and a yoga room, and “Interactive elements”, please refer to our publication from 2022 [2].

B. Video conference tool Zoom

Zoom is one of the most established Video Conferencing tools with a significant presence in the field of education, especially during the COVID-19 pandemic and in the subsequent period of reopening universities in 2021 [53] [54]. With Zoom, it is possible for one or more individuals to interact through chat messages, video based visual communication, and collaborative work [6]. Besides communication among the entire group of participants, the platform enables the creation of smaller, more focused subgroups (Break out rooms) for collaborative work or discussions. It also allows for screen sharing with other participants, the administration of brief surveys, and the use of a whiteboard. The default display is a monitor populated with video tiles representing the participants in the Zoom meeting, as illustrated in Figure 4.

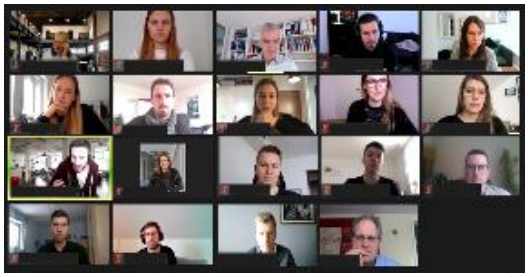

Figure 4. Video tiles on monitor while classical Zoom video conference.

C. Measuring instrument

The OLLES questionnaire in its modified 35-item format, was employed as the measurement instrument [17]. The OLLES questionnaire is a web-based survey instrument designed for use in online learning environments in tertiary education. In this context, the OLLES questionnaire provides inferences regarding students' perceptions of the opportunities for interaction within an online environment in terms of economic and efficiency considerations. The dimensions of the OLLES are Student Collaboration (SC), Computer Competence (CC), Active Learning (AL), Tutor Support (TS), Information Design and Appeal (IDA), Material Environment (ME), and Reflective Thinking (RT). Furthermore, data was collected regarding the respondents' general computer usage and internet usage. All items were measured on a 5-point Likert scale [55]. The IPQ [18] was also used. The IPQ is a scale for measuring the sense of presence experienced in a Virtual Environment. In this context, the term "sense of presence" is used to describe the subjective experience of being in a Virtual Environment. Furthermore, the igroup.org project consortium states that: “the sense of presence can be separated from the ability of a technology to immerse a user. While this immersion is a variable of the technology and can be described objectively, presence is a variable of a user's experience. Therefore, we obtain measures of the sense of presence from subjective rating scales.” The IPQ has three subscales and one additional general item not belonging to a subscale. The three subscales are Spatial Presence (the sense of being physically present in the VE), Involvement (measuring the attention devoted to the VE and the involvement experienced) and Experienced Realism (measuring the subjective experience of realism in the VE). Additionally, a general item was included to assess the overall sense of presence. This item demonstrated high loadings on all three factors, with particularly strong loadings on Spatial Presence. The original questionnaire was constructed in German, and thus, we utilized this version, as the subjects were native German speakers. All items were measured on a 7-point Likert scale, with a range from 0 to 6 [55]. Furthermore, exam grades were collected as a form of performance measure.

D. Experimental procedure

Before the first seminars, all subjects were familiarized with the Zoom resp. gather.town. In addition, the OLLES questionnaire was introduced as it was used in its original English language, but the subjects were not native English speakers. The two seminars were conducted over a period of four to five days, with each session commencing in the early afternoon and concluding approximately five to six hours later. Both seminars were held exclusively in Gather and Zoom, respectively, with a total of one measurement point occurring after the final seminar. Both questionnaires were completed online immediately following the conclusion of the seminar. As evidenced by the results of the previously conducted studies, it can be assumed that a single administration of the questionnaires is sufficient [3]. Assuming similar results for the qualitative interviews as in the previous round [2], they were not conducted for the seminars in the winter term of 2023/2024. In both the initial round conducted during the winter term of 2021/2022 and 2022/2023, it was determined that students exhibited a preference for face-to-face interactions. Given that the IPQ questionnaire is a specifically designed measurement tool for online environments, it was not utilised for the analysis of the classroom seminar, "Trend," held during the winter term of the 2023/2024 academic year.

E. Sample

The data were collected at the Technical University of Applied Sciences Würzburg-Schweinfurt during the seminars “Strategy” and “Trend” in the winter term of the 2023/2024 academic year of the Master´s Programm “Integrated Innovation Management”. The seminar “Strategy” was was conducted via Zoom ,while the seminar “Trend” face-to-face in classroom, as illustrated in Figure 1. A total of 12 participants took part in the “Strategy”-seminar. Nevertheless, only 10 subjects completed the questionnaires. This leaves a total of n = 10 valid subjects for the final analysis. The average age of the subjects is 24.3 years, with a minimum of 22 years

and a maximum of 26 years. Of the total number of 10 subjects, six were female (60.0%) and four were male (40.0%). For “Trend”-seminar given in a face-to-face setting within a classroom there where a total of n = 11 subjects, 7 female (63.6%) and 4 male (36.4%). The average age of the subjects was 24 years, with a minimum age of 22 years and a maximum age of 26 years.

IV. RESULTS

The results will be classified according to the various comparisons between the seminars and measurement tools utilised. Initially, a brief reiteration of the comparison between the OLLES outcomes for the seminar entitled "Strategy," conducted in gather.town and zoom [1]. This will be followed by the results of the IPQ questionnaire, after which the results of the examinations will be displayed. Finally, the results of the three "Trend" seminars will be presented, spanning the winter term of 2021/2022 to the winter term of 2023/2024.

Within the results of the OLLES questionnaire the general suitability for gather.town and zoom can be confirmed due to the high value of almost all the OLLES dimensions (Figure 5). The participants evaluate their “Computer Competence” (CC) quite high, also “Material Environment” (ME), “Student Collaboration” (SC) and “Tutor Support” (TS). Only “Reflective Thinking (RT) is on average level. In contrast to the results of the comparison in last round for the seminar “Trend” no significant differences were found. In the winter term of 2021/2022 versus the winter term of 2022/2023 differences were found with significant higher scores in the variables Active Learning (AL) and Information Design and Appeal (IDA) [3] for gather town. The Active Learning (AL) dimension of the OLLES specifically inquires about the motivation generated and the feedback received through activities or teaching units within the environment itself.

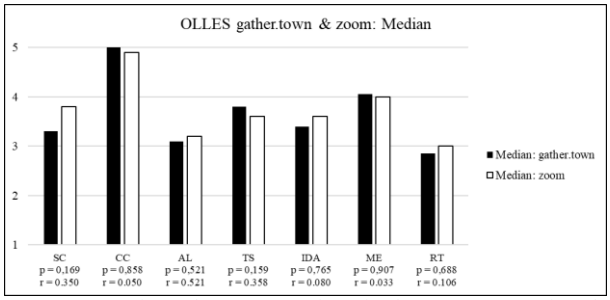

Figure 5. Comparison of OLLES questionnaire for “Strategy” seminar done in gather.town winter term 2022 versus zoom in winter term 2023.

The qualitative interviews conducted during the winter term of 2022/2023 provided confirmation that there was an increase in motivation. It was observed that this motivation was primarily the result of increased interactivity.

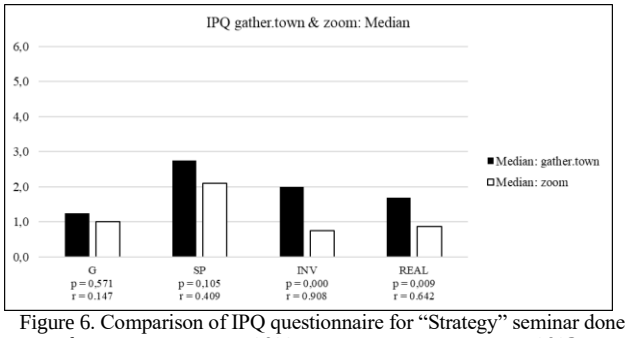

Figure 6. Comparison of IPQ questionnaire for “Strategy” seminar done in gather.town winter term 2022 versus zoom in winter term 2023.

For the test subjects, it was evident that navigating the virtual environment by moving the avatar was a more engaging experience than simply viewing the content from a stationary position [3]. This effect was not replicated in the comparison between the winter terms 2022/2023 and 2023/2024 in the seminar “Strategy”. Despite the difference in seminars, the didactic and structural elements were found to be similar, suggesting that these factors do not explain the observed discrepancy. Looking to the results of the IPQ questionnaire both virtual environments do not seem to provide an above average of immersion. All dimensions are below average, even if gather.town is generally higher than zoom (Figure 6). This confirms the results from the winter term of 2022/2023 between the seminars “Trend” and “Strategy”. For dimension “INV” and “REAL” there are significant. differences between gather.town and zoom. “INV” measures the attention you pay to VR and how involved you feel. This experience was significantly higher with gather.town (2.039) than with zoom (0.825). On a scale of 0-6, this difference is 1.21 scale points and corresponds to a strong effect size with r = 0.908. “REAL” measures how real the virtual environment/world seemed to the test subjects. This experience is significantly higher with gather.town than with zoom. But it is clearly in the negative range, close to "slightly not applicable".

When comparing the exam grades it can be noticed that the exam average for gather.town (2.1) is higher than for zoom (1.6). The same applies to the median, which is 2.3 for gather.town and 1.7 for zoom (Figure 7). The gather.town exams therefore turned out worse than those for zoom.

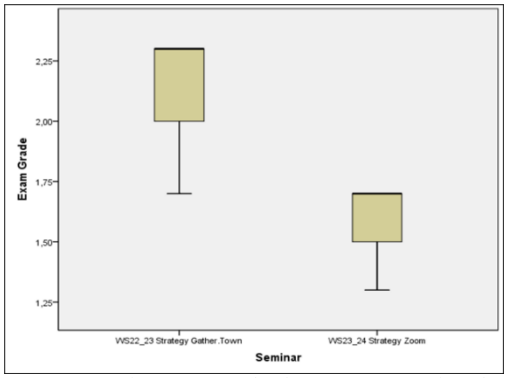

Figure 7. Comparison exam grades for “Strategy” seminar done in gather.town winter term 2022 versus zoom in winter term 2023.

It is also interesting that the exam grades for "zoom" range from 1.3 to 1.7, while for "gather.town" they range from 1.7 to 2.3. Despite this large difference, the average for zoom is lower than for gather.town. The learning success seems to be higher with the zoom environment than with gather.town. This can be confirmed by checking the significance with the U-test, because exam grades are not normally distributed. The result in Table 1 show that the mean ranks differ significantly between gather.town and zoom. The difference is around 12 ranks. This results in a z-value of -4.024 and a p of 0.000. The difference is therefore significant.

TABLE I. MANN-WHITNEY U TEST EXAM GRADES FOR "STRATEGY"

Test of Significance (U-Test)	gather.town	zoom
average rank	19.947	7.828
z =	-4.024	
p =	0.000	
effect size r	-0.735	

The effect size of r = -0.735 is also very high, it is a strong effect. This is contrary to the result of the comparison of the seminar Trend between winter term 21/22 and winter term 22/23, where the exam grades were better in the seminar given with gather.town. In the following the exam grades for the seminar "Trend" from the winter term of 2021/2022 given in gather.town, then in zoom 2022/2023 followed by face-to-face in the winter term of 2023/2024 were compared. As already published, there was a better grade for the seminar given in gather.town than in zoom [3]. Adding now the exam grades for the face-to-face seminar there is an even better learning success for face-to-face setting (Figure 8). Average for the "Trend"-seminar given in gather.town is 1,7, in zoom 1,9 and face-to-face 1,4. The same ranking is confirmed by the results for median values. Exam grades for face-to-face seminars differ significantly from gather.town-seminar (p=0 007) and effect size r = 0.564 and also Zoom-seminar (p=0 000) and effect size r = 0.844. This seems to confirm the results of the qualitative interviews where students give a clear preference to face-to-face seminars, followed by gather.town and finished by zoom [1] [3]. Probably this led to better learning results in the same hierarchy.

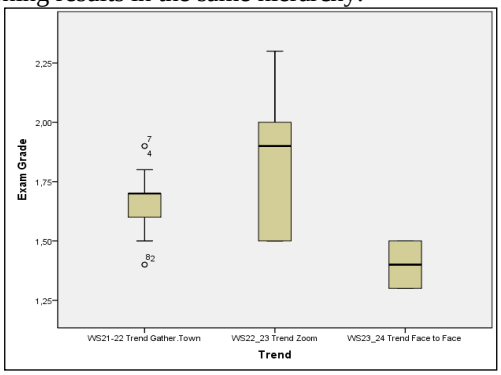

Figure 8. Comparison exam grades for "Trend"-seminar done in gather.town winter term 21/22 versus zoom in winter term 22/23 and face-to-face winter term 23/24.

V. DISCUSSION

Firstly, it can be confirmed that gather.town and zoom are suitable for tertiary education, based on the analysis of all lectures from the winter term of 2021/2022 onwards. The dimensions of OLLES are typically above average, which suggests favourable conditions for active and successful learning opportunities. When comparing the dimensions of OLLES, there are different results in terms of significance. While in the "Trend" seminar some significantly higher values were found for the dimensions "Active Learning" and "Information Design and Appeal" by comparing gather.town and zoom, this could not be confirmed in the "Strategy" seminar. Probably other aspects such as personal competences or prior knowledge are more important than the learning environment. It should be considered to improve the personal information of the students with such aspects. The results within immersion in this round confirmed the previous results. The 2D desktop environment gather.town always gets slightly higher scores in the IPQ questionnaire. But both environments get below average scores, which means that they do not provide a high level of immersion.

Looking at the results of learning success in terms of exam grades, the picture is not uniform. In the seminar "Trend" compared between the winter term of 2021/2022 and 2022/2023 better grades appeared in the lecture given in gather.town, but now we do see worse exam grades for the seminar "Strategy" given in gather.town compared to zoom. While assuming, that gather.town is more activating and motivating due to the more immersive and avatar-based environment and conducting therefore leads to better grades, this cannot be confirmed in this round. It is likely that some students are more distracted by the more immersive and activating elements. The best exam grades were achieved in face-to-face lectures in the classroom. This confirms the clear preference for face-to-face lectures that were expressed by the students [3].

However, this result cannot be generalized. This is because we are dealing with an exploratory case study and the participants are subject to change. Nevertheless, in order to generalize the results, it would be necessary to employ a representative sample. In other case studies with other subjects, the result may be different. It is possible that the participants in one seminar are simply more intellectually capable than those in another year.

VI. CONCLUSION AND FUTURE WORK

This study, with presents the partial results of the third round of the long-term study on virtual learning environments, confirms some of the previously observed results and reveals the existence of some differences. While the general suitability of 2D desktop environments, such as gather.town and also the classical video conferencing tool zoom can be confirmed, other findings, such as significant higher values and better exam grades for gather.town, could not be repeated. Due to the research frame of exploratory case study the generalizing of results is not possible [56] [57]. Probably more influencing factors, like students' pre-knowledge, IT-equipment, motivating factors or technology acceptance must

be taken into account [58] [59]. Also, the role of ethical aspects by doing online lectures in tertiary education could be addressed [60] [61]. These conclusions can be included in the preparation for the next round planned in the winter term of 2024/2025. It is intended to give the same seminars "Strategy" and "Trend" but held in a virtual 3D desktop environment (Figure 1).

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