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Lessons Learned Using a Virtual World to Support Collaborative Learning in the Classroom

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Abstract: Using technology in education is crucial to support learning, and Virtual Worlds (VWs) are one of the technologies used by many educators to support their teaching objectives. VWs enable students to connect, synchronously interact, and participate in immersive learning activities. Such VW has been developed at Sheffield Hallam University (UK), and is used to support the teaching of a specific module, as well as for conducting empirical research around the topics of Transactive Memory Systems (TMS) and Students Engagement. TMS is a phenomenon representing the collective awareness of a group's specialisation, coordination, and credibility with interesting results. This paper presents the lessons learned while using the VW over the past few years at a higher education institution to support collaborative learning within working groups. A review of these empirical findings is presented, together with the results of a follow up study conducted to further investigate TMS and student Engagement, as well as students perceived Motivation to use a VW for learning, and their Learning Outcomes. The findings of this study are corroborating and contributing to previous results, suggesting that a VW is an effective tool to support collaborative learning activities, allowing students to engage in the learning process, motivate them to participate in activities, and contribute to their overall learning experience.

Keywords: Virtual Worlds, Multi-User Virtual Environments, Immersive Learning, Computer Supported Collaborative Learning, Transactive Memory Systems, Student Engagement
Categories: L.5.1, L.0.0, L.1.1, L.2.7, L.3.3, L.3.6

1 Introduction

Using technology in education is imperative, ensuring that students (and teachers) are effectively supported during their academic years. [Cardullo et al. '17] suggests that students today are different to the students for whom the traditional educational systems were designed for. Students are now familiar with the use of the Internet and the modern digital technologies, stressing the need for education to become more active, engaging and customised to the learners' individual needs. Technology mediated and enhanced learning has now become the norm. One of the many emerging technologies educational institutions are employing for adapting to this change, is the use of Virtual Worlds (VWs). VWs are computer generated 3D environments, where students can synchronously interact with the environment and with each other through the use of avatars [Boulos et al. '07]. A 3D VW environment has been developed at Sheffield Hallam University (UK) to support the delivery of a particular undergraduate module "Introduction to ICT". Through this environment the authors conduct empirical research for investigating the concept of Transactive Memory System (TMS) and Student Engagement, the results of which have been published in several scientific papers.

This paper presents: i) a review of the papers published by the authors, in an attempt to help gain a holistic understanding of the topics of VWs for collaborative learning, ii) the results of a longitudinal study that took place to validate and investigate the previous results in more in depth approach, and iii) to evaluate the topics of students' Motivation for using a VW and the effect of the environment to students Learning Outcomes through additional quantitative and qualitative data collection and analysis. The following pages present a review of the research that has been conducted using the VW to support the module delivery; information about the development of the environment and its usage; the results of the published research to date; the results of the repeated study; it discusses its efficacy, and its future directions.

2 Background and Context

VWs are computer generated 3D worlds where users navigate and interact with the environment and each other using a virtual representation of their selves known as 'avatar' [Boulos et al. '07]. Using VWs, users immerse, and synchronously communicate, interact, and coexist in a persistent 3D graphical environment. VWs have been gaining a lot of popularity in education over the past few years [Cho et al. '17], especially from educators who are looking for effective ways to improve, differentiate, and enhance their teaching practices. The main reasons of successful adoption is that VWs provide a range of tools that cannot be found in the traditional online learning systems [Warburton et al. '16], for instance 3D graphics, environment persistency, synchronous avatar interactions, ability to be aware of the existence and actions of others in the VW etc. VWs can support synchronous participation in engaging online activities, enabling teachers to develop immersive experiences to support students learning [Jarmon et al. '09; Kamvisi et al. '15].

VWs have a number of unique attributes that contribute to the user experience, and their educational efficacy has been positively evaluated over the years [De Lucia et al. '09; Griol et al. '12; Nisiotis et al. '14; Kamvisi et al. '15; Nisiotis et al. '15, '16]. The student is provided with the feeling of 'being there', which is an attribute identified capable to increase learning and performance [De Lucia et al. '09], as well as engagement and learning success [Dede et al. '99]. Moreover, VWs make participation in activities more purposeful and meaningful, and effectively support the development of working groups [Kleanthous et al. '16; Nisiotis et al. '18].

Learning is constructed in social ways and the notion of TMS has been found very beneficial and promising on functional working groups supported by repository tools. TMS is a phenomenon representing the collective awareness of a group's specialisation, coordination, and credibility, and is concerned with: "*the prediction of group and individual behaviour through an understanding of the manner in which* *group processes and structures information*" [Wegner '87]. The focus is on encoding, storage, and retrieval of information, helping group members to be aware of each other's expertise and to divide responsibilities based on different knowledge areas. This effect provides opportunities for enhanced and effective collaboration among group members and the outcome of the collaboration is of better quality. Evidences show that the decomposition of TM into i) Specialisation, ii) Coordination and iii) Credibility between group members, helps to develop a better understanding of the aspects that affect the development of a TMS [Lewis '03]. There is a vast amount of literature in the field of organisational psychology field around the theory of TMS [Wegner '87; Lewis '03; Choi et al. '10; Theiner '13; De Leoz et al. '15; Yilmaz et al. '16]. However, the topic of TMS within teams in VW has not attracted much attention, with the exception of the work of Kahn and Williams [Kahn et al. '16] investigating TMS relating to virtual teams in virtual games, and Kleanthous et.al. [Kleanthous et al. '16] who conducted a pilot-study of the development of TMS in small task-oriented teams.

Considering the unique attributes of VWs, and the significance of establishing collaborative relationships to support learning, a VW has been used to support learning and to conduct research investigating the topic of TMS in such environments. In what follows we discuss the findings of this empirical investigation.

3 The Virtual World

The VirtualSHU VW (Figure 1) has been developed using the Opensim[1] multiuser virtual world platform. The environment is representing a common educational setting with recognisable facilities to help users understand its layout and to orientate easier. The layout features a central campus and areas equipped with different functionality each. An orientation area where students can learn the basic functionalities and navigation features of the VW is provided, together with a courtyard for students to meet, and several classrooms and collaborative areas, each dedicated to different educational topic. Each classroom was designed to provide access to PowerPoint slides, website loaders, YouTube videos and information boards to support collaborative learning. In addition, sandbox areas where the environment building and flying restrictions are lifted, and a quiet space for students who are away from keyboard but still logged in the environment are also provided. The VW also features the Robotics museum [Alboul et al. '19b, '19a], a collaboration project between the Department of Computing and the Centre For Automation and Robotics Research (CARR) at Sheffield Hallam University, which is located on the upper floor of the main campus. The museum features information about the history of robotics and several artefacts designed by students. The environment is available for everyone to use or implement, adapt, and change for their educational needs, and the research team and its developers are open to suggestions for improvements and future collaborations.

[1] Opensim: http://www.opensimulator.org

Figure 1: The VirtualSHU Virtual World

3.1 The Virtual Classroom

Since 2016, the VirtualSHU has been used to support the delivery of the 'Introduction to ICT'; a first-year undergraduate module, which typically involves 60-80 students studying in Business & Technology courses. The module delivery involves a weekly lecture followed by tutorial sessions (Table 1), which are taking place in computer labs using the VW in a blended learning approach. At the end of the semester, students are assessed though a computerised multiple choice test based on the concepts they have learned during the lectures and tutorial sessions within the VW.

Figure 2 provides details of the steps and procedures students followed to connect to the environment and participate in the learning activities. Students have a computer at their disposal to connect to the VW. To use the environment, students must register and use a specific software to connect. The students are using their keyboard and mouse to navigate and interact with the environment, and they experience the visual aspect of the environment through their computer monitor. The environment provides a 'nearby chat', which users can publicly chat to others in close proximity within the VW, Instant Messages and Group Messages for private conversations are available, as well as Voice over IP. When students connect to the environment for the first time, they are 'landed' in the orientation area, which provides information and instruction on how to use the environment, interact with objects and with each other, and how to use the communication functionalities of the VW. At the end of their orientation, during the first week, students are allocated in groups.

The educational activities used in this environment have been developed based on the McGrath's typology of tasks [McGrath et al. '93]. This is an established and validated taxonomy which illustrates types of activities to be performed at each stage of group development. Considering this taxonomy, the designed activities prompted students to generate ideas, participate and perform action tasks, solve problems, make decisions, resolve conflicts of viewpoints, and perform planning activities.

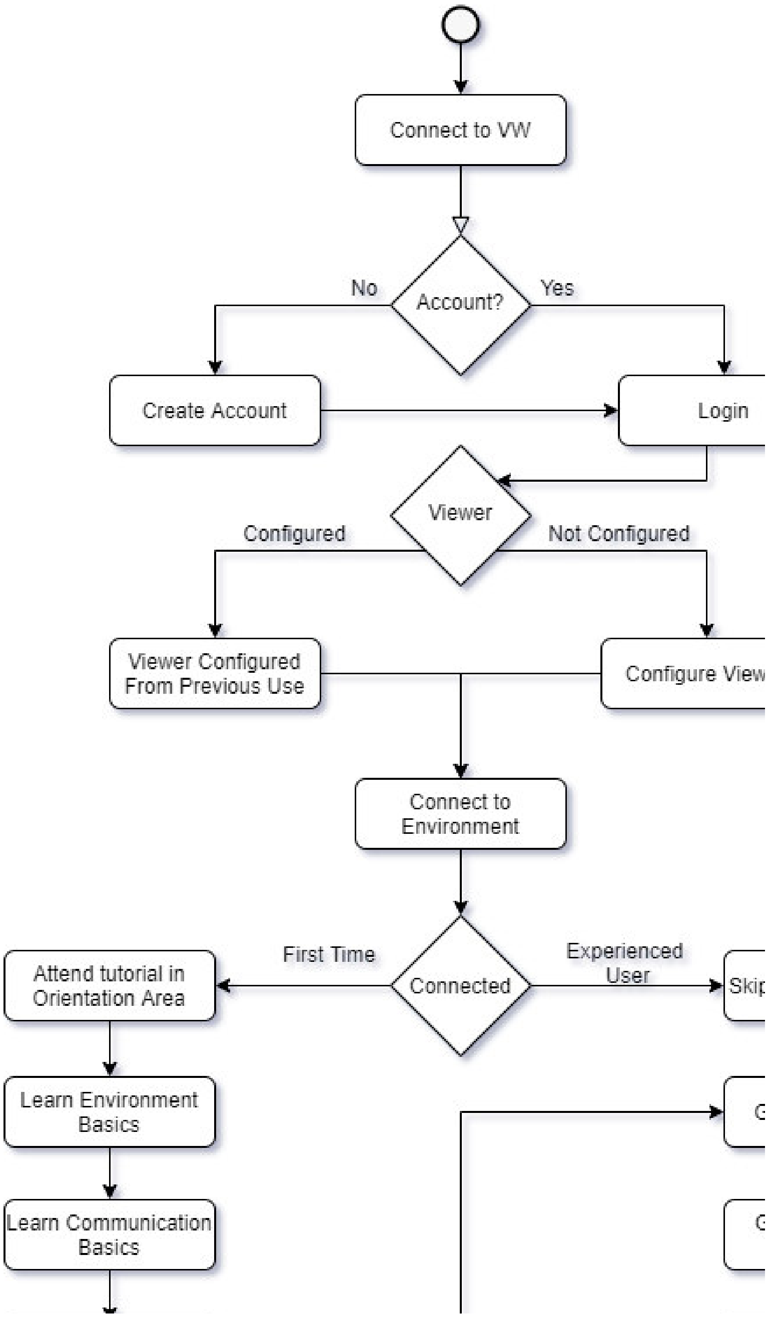

Figure 2: The Process Framework Followed by Students to Connect and Participate in Educational Activities in the VW.

Week:	Description:	Task Type
Orientation Session & Introduction to ICT		
Week 1	Students are orientating and familiarising with the environment and its functionalities. Tutors provide support when required. Team formation also takes place.	Orientation
Week 2	Icebreaking activity to discuss the topic of ICT	General Discussion
Topic 1: The Internet and the World Wide Web		
Week 3	A dedicated virtual room is allocated to each team, featuring an assigned research topic. Students have to brainstorm and create a presentation in the VW.	Generate ideas
Week 4	Students review their last week's notes to improve their own work, and present their notes in class.	Perform Tasks
Topic 2: Communication Networks		
Week 5	Questions are assigned to each group. Students review in-world materials, and perform research to create group notes to answer the questions.	Decision Making
Week 6	Students are given an interactive quiz through the VW.	Problem solving
Topic 3: Cloud Computing		
Week 7	Students are assigned a topic of research, and have to create a shared cloud document for notetaking, and preparing a presentation for the next session.	Planning
Week 8	Students have to spend some time finishing off their notes and present them in class.	Performing actions
Topic 4: The Internet of Things (IoT)		
Week 9	Groups are assigned a topic to investigate, and students review in-world information, perform independent research and prepare for a discussion	Planning
Week 10	An in-world and classroom discussion on advantages and disadvantages of IoT in everyday life. Students argue their viewpoints on the topic.	Resolving Conflicts of Viewpoint

Table 1: Description of Topics and Activities

4 TMS and Virtual Worlds

To determine the extent to which the VW is contributing towards student's collaboration and the development of social working groups during the learning process, their experience was evaluated several times. As a result, several scientific papers have been published and some are currently under review. To date, the authors have investigated and published work around the topics of the development of a TMS in VWs (Section 4.1), observed students behaviour during collaborative activities (Section 4.2), ascertained the development of a TMS in a VW over time (Section 4.3), and investigated students engagements and the relationship to TMS within a VW (Section 4.4). To ensure consistency and standardisation of research protocols and methods, the same learning delivery, materials, and activities were used in all evaluations. Students were randomly allocated in groups of 4-5 during the first week of the experiment and using a personal computer they participated in the activities described in Table 1. In order to collect data for these studies, the TMS Scale proposed by [Lewis '03] has been used, investigating the factors of Specialisation, Credibility and Coordination (5-point Likert Scale). The statistical interpretation of the scale suggests that when a TMS exists, it causes specialised knowledge, trust in each other's knowledge and coordination in tasks processing. For the study described in Section 4.4, the Students Engagement questionnaire [Sun et al. '12] was also used.

4.1 The Development of TMS in VWs

The initial experiment [Nisiotis et al. '17a] included 46 students (34 male, 12 female). Their expertise with computers and the Internet along with their experience with VWs were also measured in this study revealing that 56.6% of the participants stated to be experts in computer usage and 17.4% considered themselves as non-experts. The majority of the participants (82.6 %) self-identified as experts in Internet usage, while 45.7% had previous experience in VWs prior to the study.

The experiment results revealed the development of a TMS (M=11.04, SD=1.54), with high Specialisation (M=3.56, SD=0.58), Credibility (M=3.70, SD=0.62) and Coordination (M=3.78 SD=0.65) among students in the VW. It was also identified that students perceived Expertise in Computer Usage was positively correlated to the overall TMS development (r=0.309, p=0.037) and Coordination (r=0.351, p=0.017), and that students previous experience with VWs and Internet usage does not influence the development of TMS.

The results suggest that when utilising carefully designed group tasks that require students to become aware of each other's expertise and skills, build trust within their teams, and are aware of the knowledge that team members' possess, can contribute in effectively develop a TMS among groups in the VW.

4.2 Behavioural Observation of Users in a VW

During the experiment described above, observational investigation was also conducted focusing on the behaviour of students and their teams during the educational activities [Nisiotis et al. '17b]. It has been observed that students were engaging in the VW and were actively participating in the activities. Students used the environment's communication tools to socialise and share information and were keen on exploring the environment. During informal conversations between students and tutors, students indicated that the environment was an interesting addition to learning, enhancing their experience through the dynamism of the multimodal delivery methods. They further suggested that the environment contributed to the initial interactions between them, enabled them to build trust, sociability, and be more comfortable with each other, helping groups to develop into well performed teams.

4.3 The Development of TMS in a VW Over Time

A follow up experiment was then conducted [Nisiotis & Kleanthous '18], investigating the development of TMS over time in VWs. In this experiment, TMS was measured in two phases over a period of a full teaching semester (12 weeks).

Phase 1 data collection included participation from 51 students (38 male and 13 female) and Phase 2 included 48 students (34 male and 14 female).

Phase 1 measured TMS at week 6 of the experiment revealing moderate Specialisation (M=2.84, SD=.6), and moderate to high Credibility (M=3.63, SD =.51) and Coordination (M=3.5, SD=.55). The overall TMS development was moderate to high (M=3.3, SD=3.9). Interestingly, the results collected at the end of the experiment (Phase 2), revealed higher TMS (M=3.8, SD=.6), Specialisation (M=3.34, SD=.95), Coordination (M=4.03, SD=.68), and Credibility (M=4.1, SD=.6).

Using a Pair Sample T-Test, the results were then examined to determine whether the observed increase in the results was statistically significant, revealing strong evidence that Specialisation (t=-3.03, p=004), Credibility (t=-3.89, p=000), Coordination (t=-4.87, p=000), and the overall TMS (t=-5.27, p=000) were significantly increased over time. Moreover, results were further investigated for each group during and after the experiment, revealing that the post experiment results for the majority of the groups were higher. Therefore, further investigation to determine the extent to which there were statistically significant increase in the TMS developed between groups for the results collected during and post the experiment was then performed. A One-Way-ANOVA test was employed to investigate the statistical significance of differences between groups. The test revealed statistically significant difference for Specialisation (F(12,38)=2.413, p=.019), Coordination (F(12,38)=2.660, p=.011), and the Overall TMS (F(12,38)=3.583, p=.001) for the data collected during the experiment. There was no statistically significant difference identified between groups for Credibility (F(12,38) = .358, p = .134). These results indicated that while the majority of groups have reported the development of moderately high TM for the first 6 weeks of the experiment, not all groups had developed a consistently high TMS at that point. The results for the data collected after the experiment revealed no statistically significant differences between groups, suggesting that a consistently strong TMS has been successfully developed within all groups at the end of the experiment.

Considering the results of this study, it was suggested that while it can be argued that a period of a few weeks can be enough to initially develop a TMS in VWs, longer periods of collaboration is providing an increased TMS, indicating the need for students to work together for long periods to achieve a strong collaboration and successfully develop an effective TMS in a VW.

4.4 Students Engagement and TMS in a VW

Considering the knowledge developed around the topic of TMS and VWs, another experiment then was conducted investigating the topic of students' Engagement and the relationship between the development of TMS in a VW [Nisiotis & Kleanthous '19]. This experiment concentrated on measuring the Emotional, Behavioural and Cognitive Engagement of students within the VW using an established data collection instrument [Fredricks et al. '05; Sun & Rueda '12], and the study authors also measured the development of TMS within the groups. The study followed the same experimental conditions mentioned above and included participation of 48 students (34 male and 14 female), between 19 and 23 years old.

The results regarding TMS and its development in the VW, were once again very positive (M=3.8, SD=.6), suggesting that a TMS has been successfully established among the working groups, especially for Credibility (M=4.1, SD=.6) and Coordination (M=4.03, SD=.68). Specialisation was also moderately positively perceived (M=3.34, SD=.95), and the results confirmed that the TMS was developed, and the team members acknowledged the value of each member in the achievement of the tasks' goals. Student Engagement results were then investigated, to understand students' perceptions of their Behavioural, Emotional and Cognitive Engagement when participating in learning activities within the VW. The results revealed that students' Behavioural (M=3.93, SD=.89), Emotional (M=3.85 SD=1.07) and Cognitive (M=3.48, SD=.82) Engagement were moderately high during activities, and students revealed positive responses regarding their overall Engagement (M=3.75, SD=.77) with the module through the VW.

The results of this study also confirmed that there is positive correlation between Student Engagement and the development of TMS in a VW (Table 2). A Pearson correlation test was employed, revealing positive correlation (r=.567, p=0.000), between TMS and Engagement, as well as interesting correlations among the individual factors comprising TMS and Engagement. In particular, the tests revealed positive correlation between Specialisation and Cognitive Engagement (r=.56, p=0.000) indicating that the specialised knowledge and/or skills that members possessed relate to the students Cognitive Engagement. Credibility was found to positively correlating to Behavioural (r=.51, p=0.000) and Emotional Engagement (r=.42, p=0.003), indicating that the development of Credibility relates to the students level of involvement in terms of Behaviour and Emotional engagement to the module. Last but not least, positive correlation was also identified among Coordination with Behavioural Engagement (r=.53, p=0.000), and moderately positive correlation for Emotional (r=.38, p=0.007) and Cognitive Engagement (r=.32, p=0.029), indicating that in order to coordinate actions within group activities, students need to be highly engaged to the task.

Spec	-	.34*	.44**	.24	.24	.56**
Cred	.34*	-	.69**	.51**	.42**	.29*
Crd	.44**	.69**	-	.53**	.38**	.32*
BE	.24	.51**	.53**	-	.7**	.39**
EE	.24	.42**	.38**	.7**	-	.42**
CE	.56**	.29*	.32*	.39**	.42**	-
*significant at the 0.05 level / ** significant at the 0.01 level.						

Table 2: Correlation Results

Observations during the experiment also took place though monitoring students behaviour and communication during the learning activities by the teaching team, indicating that students were successfully engaging in activities that required the team to delegate tasks in pairs or individuals. It was observed that activities requiring input from all students for a successful completion, encourages students to contribute in order to ensure they satisfy the rest of the team. It was also observed that the longer students were involved in the activity, the more they engaged and were being productive. Furthermore, students were engaging and persisting in trying to complete activities when rewards were offered upon task completion. The authors also observed that the more the students were required to interact with each other, the more they kept engaged during the learning activities. Active students appeared to attract the attention of disengaged students or lurkers. Students were informally enquired about their group work in weeks 5 and 6, suggesting that as time passed their collaboration evolved, confirming the previous results mentioned in [Nisiotis & Kleanthous '18], indicating that they were becoming more confident in coordinating, communicating, and delegating activities based on each other's skills, and trusted each other to complete assigned tasks. Students also appreciated the immersive feeling of the environment and suggested that it was an interesting, sociable, and enjoyable addition to learning. However, some students indicated that the 'gaming like' element of the environment was found as a distraction, providing examples of students disengaging from the activity when finishing assigned tasks early.

Based on the results and observations of this experimental study, a series of suggestions and considerations for the development and design of educational activities in VWs were devised and presented [Nisiotis & Kleanthous '19].

5 Research Methodology

Considering the knowledge developed during the experimental studies conducted and presented so far in this paper, the authors considered important to conduct additional experimentation to develop an in depth understanding of the topic of Student Engagement and the development of TMS within VWs. Furthermore, the topic of Student Motivation in participating in learning activities through a VW, and the effect of this environment effect to their Learning Outcomes was also set to be investigated, to develop a more coherent understanding of the student experience with the learning tool. To investigate this, the following research questions have been formulated:

- RQ1 - To what extent TMS has been successfully developed within the working groups while undertaking learning activities in the VW?
- RQ2 - What are the students' perceptions of their Behavioural, Emotional and Cognitive Engagement when participating in learning activities within the VW?
- RQ3 - How motivated are students to learn when participating in learning activities in the VW?
- RQ4 - What are the students' perceptions of their learning outcomes using the VW?

The experimental procedures as presented in Section 3.1 were also adopted in this study to ensure consistency of experiments. Students participated in this experiment in weekly sessions for a period of 10 weeks, following the topics and activities described in Table 1. Each session lasted for 60 minutes, and all learning activities were taking place through the VW. Students had a computer at their disposal, and they were co-located in the same room. To collect data for the needs of this study, a mixture of quantitative and qualitative data collection and analysis approach was adopted.

To measure the development of TMS among groups working within the virtual world, the Transactive Memory System scale as developed by [Lewis '03] was adopted (see also above). To measure the Student Engagement in the VW, the Engagement Scale [Fredricks et al. '05; Sun & Rueda '12] was adapted, aiming at measuring three types of Student Engagement: Behavioural, Emotional and Cognitive Engagement. [Fredricks et al. '05] have initially designed the scale to measure children levels of school engagement, and [Sun & Rueda '12] had modified some of the items to measure engagement of graduate and undergraduate students in distance education settings. To adopt the scale and ensure its appropriateness to the purpose of the needs of this investigation, the study authors further modified the scale and removing two items relating to homework and revisiting recorded lectures (BE5 and CE7 from [Sun & Rueda '12]), as these were not applicable.

To investigate the topic of students perceived Motivation in the VW during the learning experiences, the questions related to Motivation from the questionnaire used by [Eom et al. '16] were adapted. This is a wider concept questionnaire investigating several determinants of students perceived learning outcomes and satisfaction in online education. From the same questionnaire, the questions in relation to Learning Outcomes were used and adapted to the context of this investigation. The data collection involved 28 participants (20 males, 8 females) between 19 and 23 years old. Students have been administered an online questionnaire[2] at the end of the experiment.

Students were then invited for interviewing, to gain a better understanding of the topics of TMS, Engagement, Motivation and Learning Outcomes when participating in the VW during the collaborative activities. A focus group data collection method was employed to collect[2] and analyse qualitative data. Three focus group sessions with the total participation of 18 students were conducted, and each session lasted one hour. To analyse the collected data, we have employed thematic analysis [Braun et al. '06], and the results are organised in themes emerged during the data analysis stage and presented in Section 6.2.

6 Results

6.1 Questionnaire Results

Prior to conducting data analysis, the data was tested for normality using a Kolmogorov Smirnov normality test and identified to be normally distributed (Figure 3); hence parametric tests have been used.

[2] Data Collection Instruments: http://virtualshu.com/survey

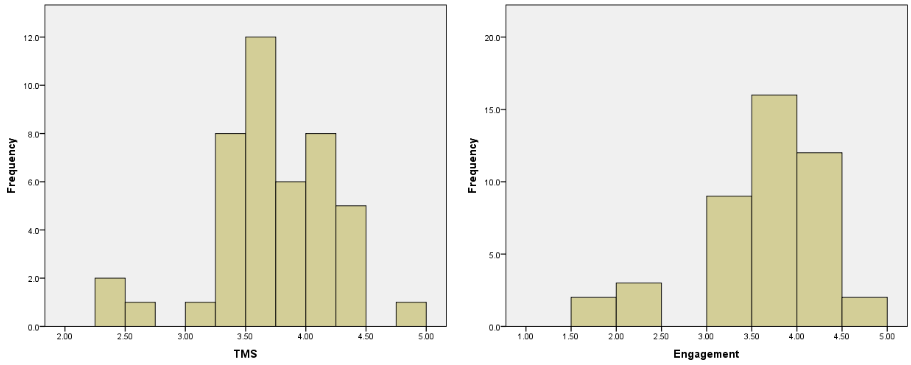

Figure 3: Data Distribution

The TMS results were investigated first (Table 3), revealing positive perceptions towards the factors of Coordination (M=3.9, SD=.68), Credibility (M=4, SD=.67) and Specialisation (M=3.4, SD =.94), and the Overall TMS (M=3.8, SD=.6). The TMS results are consistent with the previous studies presented in this paper [Nisiotis et al. '17a; Nisiotis & Kleanthous '18; Nisiotis & Kleanthous '19], confirming the development of TMS among the working groups, and addressing the RQ1 posed in this study.

	Mean	SD	Min	Max
Coordination	3.9	.68	2.8	5
Credibility	4	.67	2	4.8
Specialisation	3.4	.94	2	5
Overall TMS	3.8	.6	2.5	4.9

Table 3: TMS Results

To investigate RQ2, the Engagement results were then analysed (Table 4). Students have positively perceived Behavioural (M=3.81, SD=.52), Emotional (M=4.08, SD=.71) and Cognitive Engagement (M=3.3, SD=.83), with high overall perceptions of Engagement during the collaborative learning activities in the VW (M=3.73, SD=.54). The Engagement results of this study are also consistent with the results presented in our previous study [Nisiotis & Kleanthous '19], addressing RQ2 and indicating that students are indeed engaging and develop high Cognitive, Behavioural and Emotional engagement during activities within the VW.

	Mean	SD	Min	Max
Behavioural Engagement	3.81	.52	2.5	5
Emotional Engagement	4.08	.71	2.7	5
Cognitive Engagement	3.3	.83	1.7	4.7
Engagement Overall	3.73	.54	2.4	4.6
Motivation	3.77	.66	2.2	5
Learning Outcomes	3.59	1.07	1	5

Table 4: Student Engagement, Motivation and Learning Outcomes Results

To investigate RQ3 and RQ4, the collected data focussing on students Motivation and their Learning Outcomes were then analysed (Table 4). The results revealed that students appeared to be motivated (M=3.77, SD=.66) to participate in the collaborative activities within the VW, and have positively perceived their overall Learning Outcomes while using the VW (M=3.59, SD=1.07). In particular, 71% of the students agreed that the academic quality of the VW is on par with face-to-face classes they have taken, and 67.9% agreed that they have learned as much from the VW as they might have from a face-to-face classroom. In fact, more than half of the students (52.89%) indicated that they learn more during their presence in the environment than in traditional classes and as much as 57.2% indicated that the quality of the learning experience in the VW is better than in face-to-face classes.

The quantitative results of this study are consistent and corroborating the findings from the previous studies presented in Section 4 of this paper, suggesting that TMS can successfully be developed within groups in the VW. The findings revealed that specialisation in different skills and roles was occurring among group members during the educational activities, and they were effectively coordinating efforts based on credible information sharing and collaboration to ensure the quality of deliverable, and tasks completion. The results also indicate that students were motivated to participate in the learning activities, and that the use of the VW as a learning platform has contributed on their learning outcomes.

6.2 Qualitative Results

To gain an in depth understanding of students' collaborative experience during the learning activities and ascertain the RQs posed in this study, a series of focus group sessions were also conducted. Students were enquired about their collaborative experience, engagement, levels of motivation during the learning activities within the VW and the effect of the environment to their learning outcomes, and a number of interesting insights have emerged and presented below.

6.2.1 Specialisation in the Group

The data analysis began by discussing the topic of Specialisation within the group. Students suggested that while they did not have any specific specialisation areas when teams were initially formed, they have developed specific skills over the time during the module, and they have utilised them when needed within the VW.

Participant 6: *"I ended up being good at referencing, so I was responsible for citing and formatting citations in the references list… the rest of my group were giving me the sources and I was formatting them properly"*

It was also determined that when students had previous experience with specific topics, they took ownership of the task and the rest of the team members contributed with supporting roles.
Participant 2:*"One of our group members covered Internet of Things at College and she had good knowledge and experience on the topic, so we have decided that she was going to assign specific tasks for us and then she would put everything together to complete the activity"*

However, some participants indicated that they did not focus on any particular specialised skills during activities, but were all contributing to the activities instead, regardless of their preferred specialised skills. Participants also indicated that this have contributed to developing a sense of togetherness in the group.

Participant 11:*"We all contributed in the activities and helped each other… we didn't consider any specific skills, we were all involved on pretty much everything together"*

A specific participant highlighted that his group was not very communicative and there was not much involvement from the majority of the group members, who ended up spending time browsing irrelevant materials rather than concentrating on the task at hand.

Participant 5 *"There was not good communication in our team… we used our own experience and each student was doing their own individual research."*

The participant further explained that due to poor group dynamics and miscommunication, the group deliverable had duplicate information entries due to students working on the same tasks.

Participant 5: *"We ended up doing our own individual investigation and many times we ended up working on the same thing which was a bit embarrassing when we had to discuss our findings in classroom… we simply didn't work with each other in the group"*

6.2.2 Group Coordination

The question regarding how group members were coordinating activities and tasks within the environment was then investigated. In general, participants agreed that the coordination between group members was quite effective and productive. Participants indicated that task delegation was important in order to manage and complete the learning activities. Participants explained that determining the workload of each task prior delegating to ensure fairness of contribution was initially taking place, and when students finished their assigned task(s) earlier than others, they began reviewing, supporting and contributing to each other's work.

Participant 12 *"Each person was assigned a task usually, but when a task was harder than other, two persons where assigned, or others were taking more tasks… when finished, we then kept on adding information and helping each other"*

The use of the textual chat has been identified as an important tool to facilitate and better manage coordination within the groups, as it allowed establishing communication for information sharing, and socialisation.

Participant 10: *"Using the chat really helped us to talk to each other. For example when we were sitting in a row, far from each other, or many times we were watching YouTube on headphones, and we were using the chat for notes, sharing links, and references."*

However, the specific participant whom his group was not effectively working together, repeated his view:

Participant 5: *"As I said before, there was not much communication and coordination in my group unfortunately. We did not delegate, we barely talked to each other and we simply did our own thing with not so great results."*

6.2.3 Group Credibility

Regarding the question focussing on group Credibility, the majority of participants indicated that there was a lot of trust and credibility around the information circulated between members during tasks. Participants explained that they mainly believed what their group members were sharing, and they based their learning on this information sharing process.

Participant 17: *"We were trusting each other in my group! We all wanted to make sure that the information we shared was correct, therefore we cited and referenced everything, at the end of the day we were going to use the materials to revise for the exam"*

It was also pointed out that when an issue or a mistake was identified, students corrected each other, and participants suggested that this was contributing to the level of trust and togetherness even more.

Participant 11: *"There was a lot of trust in our group and faith on our information sharing. There was some double checking when unsure but in general we were trusting each other."*

Interestingly, two of the participants which their group was not as effective and productive as others, indicated that they would double check information to ensure its correctness.

Participant 6: *"I didn't really trust what others were saying and I was double checking to see if the information was correct"*

6.2.4 Engagement in the Virtual Environment

To ascertain RQ2 and better understand the extent to which students were engaging during the activities, participants were directly enquired about their learning experience in the VW. Participants agreed that the environment was very engaging. Participants indicated that one of the most important factors that contributed to their engagement was the layout of the environment, in particular by allowing learning materials to be near each other, allowing them to see each other's avatars, helping them to identify areas and materials of common interest. Participants indicated that they could navigate around and find information based on visual metaphors in the environment, and they had all the information in one place rather than switching between browser tabs and software applications.

Participant 3 *"It was very engaging, all the slides were near each other, websites and information next to each other. I could see a YouTube sign and I could immediately understand what this was about… Not switching through apps, everything was around you to navigate and access easily"*

Participants also suggested that the way information was provided through the virtual world was very engaging as it allowed them to easily access the materials that were spread around in the rooms.

Participant 16 *"You could click on objects revealing information to help you do your research, and it was very easy to find info and locate group members and know what they are doing."*

A participant highlighted that due to the dynamic nature of the environment, it was very easy for the tutor to add new information when needed, with all participants of that particular focus group explicitly agreeing with this and giving examples.

Participant 1 *"It is also easier for teacher to put things online... for instance when [name omitted] found the PDF showing statistics of Internet Use and you [the tutor/interviewer] immediately edited the room to add it for the rest of us."*

Students also indicated many occasions which they lost track of time while engaging with learning activities in the VW.

Participant 2: *"After a while when I was working on my part of the activity, I ended up losing track of time"*

The ability to communicate through the VW was also found as an engaging aspect of the environment, enabling students to establish communication and share information.

Participant 15 *"We were using the chat to communicate a lot, we shared information all the time using it, for example sharing links to resources"*

Participants also identified that the interactive nature of the environment was also very engaging and compared them to the traditional learning methods.

Participant 13: *"It is a lot more interesting and interactive rather than just looking at a boring screen, and doing individual research"*

However, students who experienced collaboration or communication issues in their group, revealed that these issues had a strong impact on their engagement mainly because they felt that they were working alone in the environment without significant input from the rest of the team.

Participant 10: *"There was very little involvement from the rest of the group, some never attended, and this challenged my engagement. It was exciting at first but then with no communication and involvement it was not working for me."*
Participant 12: *"Was it the work given? "*
Participant 10: *"No, no, it was combination of people in the group that didn't work! "*

6.2.5 Motivation to use the Environment

Students were then queried the extent to which the VW was motivating them to participate in the learning activities, and to our surprise, all participants agreed that the environment was a motivating factor.

Participant 14 *"I attended every seminar because of it. I was a lot more motivated to use it. It was very different to the standard teaching, there was a lot of interaction, new interface, new type of learning, it was great!"*

Students indicated a number of reasons which motivated them to participate in activities including: the fun element of the environment, high perceptions of engagement, the ability to allow them to easily conduct research using the tools provided in the VW to take notes and to share information. Students also revealed that they could undertake activities in their own pace and suggested that the environment takes away the formality of the traditional classroom.

Participant 4: *"I have attended all session as well. It was very motivating and interesting… easy to do work in my own pace… Allowing me to work in my own pace to get work done, and then navigate around the environment to relax."*

Interestingly, participants who revealed group related issues hindering their work and collaboration, suggested that the environment was still motivating and a nice addition to learning.

Participant 10: *"I don't blame the environment; it was just my group that was not working. In fact, the environment was the fun and motivating part of the day! I could then do my work individually in a more interesting environment than just my computer screen and a word document"*

6.2.6 Distractions of the Virtual Environment

Based on the findings presented in [Nisiotis & Kleanthous '19], the topic of the environment as a distraction was investigated. Specifically, some participants indicated that the game-like element of the environment was somewhat of a distraction from learning and the scope of the activities mainly during the first few weeks of the environment usage. This finding is consistent with the results identified in [Nisiotis & Kleanthous '19] and discussed in Section 4.4. However, participants suggested that with the passing of time, they were understanding the environment's purpose in the module delivery, and they were concentrating to complete the tasks at hand, forgetting the gaming element of the environment.

Participant 17: *"In the beginning I was very excited, trying to fly around, climb on walls etc. But after me and the team started realising that this tool would be the main delivery method of the module, we all concentrated on using it properly, and I can say that it was a nice distraction!"*

Other participants indicated that the environment was taking away the formality of the traditional classroom, and they enjoyed this method of learning rather than considering it as a distraction.

Participant 13: *"It was a good distraction, allowing us not being too serious, and taking away formality. In the beginning we were taking videos and sharing pictures with our avatar – a lot of students did put these pictures on their social media! Then it sort of became a tool that we enjoyed working with"*

7 Discussion

The use of VWs to support education is a topic that drew a lot of interest during the past decade, and there were many successful implementations of such technology to deliver educational materials and to enhance learning and teaching practices [Nisiotis et al. '16]. Such VW is in use at Sheffield Hallam University (UK) to support the delivery of a specific module with great success. Using this environment, several empirical studies have been conducted focusing on the collaborative experience of students during the learning activities followed by evaluation of students Engagement [Nisiotis & Kleanthous '19], providing important insights and lessons about the efficacy of VWs to support education. In addition to these findings, the study presented in this paper features a repeated experimental approach following the same learning activities and experimental procedures of the previously conducted studies, further investigating TMS and Student Engagement. Moreover, this study is adding value to the previous experiments, by corroborating and validating their findings, and investigating student's perceived Motivation to participate in the VW, and the impact of the environment on their Learning Outcomes. Furthermore, a qualitative investigation collecting data based on students' opinions, thoughts, and concerns around the use of such technology for learning was also conducted.

From the experience developed using the VW in the classroom and the results of the experimental studies presented in this paper, many important lessons were learned. One of the most important learning outcomes is that the VW can effectively support the development of TMS, and the longer students work together in the same group within the VW, the better is the collaboration, facilitating high levels of TMS. While collaboration and the development of an initial TMS can be achieved from early stages, more time can help groups to develop strong working relationships that are built on trust, credibility of information development and sharing, awareness of each other's skills, and help to better coordinate during activities. In addition, the environment can effectively engage students in learning activities and keep them motivated to participate. The environment can behaviourally, emotionally and cognitively engage students in the learning process. It was also identified that the levels of students' Engagement in the VW are significantly correlated with the factors that contribute to the development of a TMS within the environment. In general, students perceived the VW as a platform where they can immerse and participate in educational activities that are different than the traditional classroom activities, enriching their learning experience.

However, the environment can also pose learning distractions, and this needs to be taken under deep consideration by virtual world designers and educators. There were occasions when the group collaboration was identified as not effective due to several reasons. A suggestion for educators based on the authors experience is to consider intervening, moderating and ensuring that students are engaging with the activities. Educators could resolve the situation by either assigning direct tasks to students, or even reshaping and reforming groups, as ineffective group collaboration is negatively impacting the students' learning experience.

8 Conclusions and Future Work

Considering the results of the experiments described in this paper holistically, it can be argued using a VW in the classroom: i) can support effective collaboration between students; ii) positively contributes towards the students learning experience; iii) can engage and motivate students to participate in immersive learning activities; iv) can successfully support the development of the TMS among working groups; v) and is a useful addition to the module delivery methods that positively contributes towards students learning outcomes. The educational efficacy of the environment is demonstrated by the fact that the module delivery and its learning outcomes are achieved as targeted each academic year, from the evident effectiveness of the students' interactions, and the quality of their deliverables.

While the environment will keep being the primary teaching method of the Introduction to ICT module practical sessions, further research projects have been planned. The environment will keep being developed to improve its layout and to provide additional functionalities. Considering that its efficacy and effectiveness have been established, the environment will be advertised as a platform for undergraduate and postgraduate students to conduct their own research and make it available to use for their final projects.

Furthermore, the future directions of this environment is to be converted into a new type of conceptually led Cyber-Physical-Social Eco-Society system that seamlessly blends the real with the digital worlds worlds, engendered by humans using XR, Robots and Social Networking technologies to support immersive learning [Nisiotis & Alboul, '20]. The research team behind this environment is also working on developing such a system to support cultural heritage [Alboul et al. '19b, '19a; Nisiotis, Alboul, et al. '19; Nisiotis et al. '20] based on a framework for generic application [Nisiotis et al. '20], and its implementation would benefit students by enabling them to learn complex concepts more effectively and experience the future of immersive learning technologies.

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References

[Alboul et al. '19a] Alboul, L., Beer, M., & Nisiotis, L.: Merging Realities in Space and Time: Towards a New Cyber-Physical Eco-Society; M. Dimitrova & H. Wagatsuma, (Eds.) Cyber-Physical Systems for Social Applications, Pensylvania, USA Doi: 10.4018/978-1-5225-7879-6. 2019a.

[Alboul et al. '19b] Alboul, L., Beer, M., & Nisiotis, L.: Robotics and Virtual Reality Gaming for Cultural Heritage Preservation. Proc. Resilience and Sustainability of Cities in Hazardous Environments, Napoli, 2019, 2019b, 335-345.

[Boulos et al. '07] Boulos, M. N., Hetherington, L., & Wheeler, S.: Second Life: An Overview of the Potential of 3-D Virtual Worlds in Medical and Health Education; Health Information and Libraries Journal, 24, 4, 2007, 233-245.

[Braun & Clarke '06] Braun, V., & Clarke, V.: Using Thematic Analysis in Psychology; Qualitative Research in Psychology, 3, 2, 2006, 77-101.

[Cardullo et al. '17] Cardullo, V. M., Wilson, N. S., & Zygouris-Coe, V. I.: Enhanced Student Engagement through Active Learning and Emerging Technologies; Student Engagement and Participation: Concepts, Methodologies, Tools, and Applications, 2017, 399.

[Cho & Lim '17] Cho, Y. H., & Lim, K. Y.: Effectiveness of Collaborative Learning with 3D Virtual Worlds; British Journal of Educational Technology, 48, 1, 2017, 202-211.

[Choi et al. '10] Choi, S. Y., Lee, H., & Yoo, Y.: The Impact of Information Technology and Transactive Memory Systems on Knowledge Sharing, Application, and Team Performance: A Field Study; MIS quarterly, 2010, 855-870.

[De Leoz & Khazanchi '15] De Leoz, G., & Khazanchi, D.: Exploring the Influence of Trust in the Development of Transactive Memory Systems in Virtual Project Teams. Proc. MWAIS, 2015.

[De Lucia et al. '09] De Lucia, A., Francese, R., Passero, I., & Tortora, G.: Development and Evaluation of a Virtual Campus on Second Life: The Case of SecondDMI; Computers & Education, 52, 1, 2009, 220-233.

[Dede et al. '99] Dede, C., Salzman, M. C., Loftin, R. B., & Sprague, D.: Multisensory Immersion as a Modeling Environment for Learning Complex Scientific Concepts; Modeling and Simulation in Science and Mathematics Education, 1999, 282-319.

[Eom & Ashill '16] Eom, S. B., & Ashill, N.: The Determinants of Students' Perceived Learning Outcomes and Satisfaction in University Online Education: An Update; Decision Sciences Journal of Innovative Education, 14, 2, 2016, 185-215.

[Fredricks et al. '05] Fredricks, J. A., Blumenfeld, P., Friedel, J., & Paris, A.: School Engagement; What Do Children Need to Flourish?, 2005.

[Griol et al. '12] Griol, D., Molina, J. M., de Miguel, A. S., & Callejas, Z.: A Proposal to Create Learning Environments in Virtual Worlds Integrating Advanced Educative Resources; Journal of Universal Computer Science, 18, 18, 2012, 2516-2541.

[Jarmon et al. '09] Jarmon, L., Traphagan, T., Mayrath, M., & Trivedi, A.: Virtual World Teaching, Experiential Learning, and Assessment: An Interdisciplinary Communication Course in Second Life; Computers & Education, 53, 1, 2009, 169-182.

[Kahn & Williams '16] Kahn, A. S., & Williams, D.: We're All in This (Game) Together: Transactive Memory Systems, Social Presence, and Team Structure in Multiplayer Online Battle Arenas; Communication Research, 43, 4, 2016, 487-517.

[Kamvisi et al. '15] Kamvisi, M., Kleanthous, S., & Nisiotis, L.: Experiences of Collaborating and Learning through Collab3Dworld. Proc. Workshop, Short Paper and Poster Proceedings from the inaugural Immersive Learning Research Network Conference, Prague, CZ, 2015.

[Kleanthous et al. '16] Kleanthous, S., Michael, M., Samaras, G., & Christodoulou, E.: Transactive Memory in Task-Driven 3D Virtual World Teams. Proc. Proceedings of the 9th Nordic Conference on Human-Computer Interaction (ACM), 2016, 93.

[Lewis '03] Lewis, K.: Measuring Transactive Memory Systems in the Field: Scale Development and Validation; Journal of Applied Psychology, 88, 4, 2003, 587-603.

[McGrath & Hollingshead '93] McGrath, J. E., & Hollingshead, A. B.: Putting the" Group" Back in Group Support Systems: Some Theoretical Issues About Dynamic Processes in Groups with Technological Enhancements; Group support systems: New perspectives, 1993, 78-96.

[Nisiotis & Alboul, '20] Nisiotis, L, & Alboul, L: Work-in-Progress—Converging Virtual Reality, Robots, and Social Networks to Support Immersive Learning. In the Conference Proc. 6th International Immersive Learning Research Network (iLRN), 308-311.

[Nisiotis et al. '19] Nisiotis, L., Alboul, L., & Beer, M.: Virtual Museums as a New Type of Cyber-Physical-Social System. Proc. International Conference on Augmented Reality, Virtual Reality and Computer Graphics, 2019, 256-263.

[Nisiotis et al. '20] Nisiotis, L., Alboul, L., & Beer, M.: A Prototype That Fuses Virtual Reality, Robots, and Social Networks to Create a New Cyber–Physical–Social Eco-Society System for Cultural Heritage; Sustainability, 12, 2, 2020, 645.

[Nisiotis et al. '14] Nisiotis, L., Beer, M., & Uruchurtu, E.: The Evaluation of SHU3DED Cyber Campus - a Pilot Study. Proc. The 14th International Conference on Advanced Learning Technologies, 2014, 688-690.

[Nisiotis et al. '15] Nisiotis, L., Beer, M., & Uruchurtu, E.: The Evaluation of a Cyber Campus to Support Distance Learning Activities. Proc. Workshop, Short Paper and Poster Proceedings from the inaugural Immersive Learning Research Network Conference, Prague, CZ, 2015.

[Nisiotis et al. '16] Nisiotis, L., Beer, M., & Uruchurtu, E.: The Use of Cyber Campuses to Support Online Learning for Students Experiencing Barriers Accessing Education; (EAI) Endorsed Transactions Future Intelligent Educational Environments, 2, 6, 2016.

[Nisiotis et al. '17a] Nisiotis, L., Kleanthous Loizou, S., Beer, M., & Uruchurtu, E.: The Development of Transactive Memory Systems in Collaborative Educational Virtual Worlds; Immersive Learning Research Network: Third International Conference, iLRN 2017, Coimbra, Portugal, June 26–29, 2017. Proceedings. Cham: Springer International Publishing, 2017a.

[Nisiotis et al. '17b] Nisiotis, L., Kleanthous Loizou, S., Beer, M., & Uruchurtu, E.: The Use of a Cyber Campus to Support Teaching and Collaboration: An Observation Approach. Proc. The Immersive Learning Research Network (iLRN) Conference 26-29 June 2017, 2017b.

[Nisiotis & Kleanthous '18] Nisiotis, L., & Kleanthous, S.: The Development and Evolution of Transactive Memory System over Time in Muves. Proc. 10th Computer Science and Electronic Engineering Conference, 2018.

[Nisiotis & Kleanthous '19] Nisiotis, L., & Kleanthous, S.: The Relationship Between Students' Engagement and the Development of Transactive Memory Systems in MUVE: An Experience Report. Proc. Proceedings of the 2019 ACM Conference on Innovation and Technology in Computer Science Education, 2019, 71-77.

[Sun & Rueda '12] Sun, J. C. Y., & Rueda, R.: Situational Interest, Computer Self-Efficacy and Self-Regulation: Their Impact on Student Engagement in Distance Education; British Journal of Educational Technology, 43, 2, 2012, 191-204.

[Theiner '13] Theiner, G.: Transactive Memory Systems: A Mechanistic Analysis of Emergent Group Memory; Review of Philosophy and Psychology, 4, 1, 2013, 65-89.

[Warburton & García '16] Warburton, S., & García, M. P.: Analyzing Teaching Practices in Second Life; Learning in Virtual Worlds: Research and Applications, 2016.

[Wegner '87] Wegner, D. M.: Transactive Memory: A Contemporary Analysis of the Group Mind; Theories of Group Behavior. Springer, 1987.

[Yilmaz et al. '16] Yilmaz, R., Karaoglan Yilmaz, F. G., & Kilic Cakmak, E.: The Impact of Transactive Memory System and Interaction Platform in Collaborative Knowledge Construction on Social Presence and Self-Regulation; Interactive Learning Environments, 2016, 1-21.