REFLECTIONS ON DESIGN OF ACTIVE LEARNING MODULE FOR TRAINING EMERGENCY MANAGEMENT PROFESSIONALS IN VIRTUAL REALITY

Molka-Danielsen, Judith, Molde University College, NOR, j.molka-danielsen@himolde.no

Prasolova-Førland, Ekaterina, NTNU, Trondheim, NOR, ekaterip@ntnu.no

Fominykh, Mikhail, Molde University College, NOR, mikhail.fominykh@himolde.no

Lamb, Katherine, Effective Command, UK, katherine@klambassociates.com

Abstract

Experiences gained through learning design projects can be used as the basis to build systematic knowledge of digitization and active leaning in higher education. One such project funded by the Norwegian Agency for Digital Learning in Higher Educations (Norgesuniversitetet) has explored the design and trialling of a new resource for Emergency Management education that is based on theories of Active Learning and applies an innovative use of virtual reality technologies (VR). The project develops an active learning module (ALM) in a specialized VR simulation. The ALM has the learning objective to aid Emergency Management and Health professional students in the training of communications in management during a crisis situation. The student interactions in the virtual reality simulated ALM are active learning, because they are required to make real-time decisions while (1) interacting with the simulated environment and (2) they are communicating with colleagues within profession and across professions. This paper is based on observed and collected data from two days of trials using the ALM, with non-professional students in April 2016 and with Emergency Management and Health professional students in March 2017. The purpose of this paper is not to report on the learning outcomes for the students participating in these particular trials. Rather, based on the experiences of the trial-runs, the educational module (ALM) designers will reflect on the educational challenges within the thematic area. We will describe and discuss the elements of the active learning design such as the learning activities, the assessment forms, and the organizational implementation within the thematic educational programs. We will discuss how technology plays a role in achieving or hindering active learning objectives. Finally, we will reflect on how future designs of ALM can be further developed to better meet the learning needs of the primary target learning group.

Keywords: Active Learning, Virtual Reality, Emergency Management Training.

1 Introduction

This paper aims to contribute to the systematic building of knowledge on digitalization and active learning in higher education. We describe the feedback and experiences in the development and trialling an active learning module (ALM) applied in a specialized VR simulation. The ALM has the learning objective to aid Emergency Management and Health professional students in the training of communications in management during a crisis situation.

The aim for the active learning design in the 2 year project funded by the Norwegian Agency for Digital Learning in Higher Education "Norgesuniversitetet" (NUV) is to create an EM active learning module using VR (VR-ALM) that will be implemented in several courses for an Emergency Management continuing education program ("Beredskap" BSK EUV program) at Molde University College (HiM) and with ninth term medical students at the Norwegian University of Science and Technology (NTNU). The VR-ALM is a mediating tool that aims to support the learning objectives of the active

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learning module. This project aims to contribute to the improvement of the EM continuing education program and to improvement in practical placement programs in crisis management for medical students at the targeted higher education institutions.

In 2016 and 2017 the project team completed an initial design of a VR-ALM simulation and have trialled it on two occasions; one day with a non-professional group and on another day with diverse professional groups. After each day of trials the project team reflected on the feedback of the participants and experts and then further improved the simulation. The project has developed the VR-ALM simulation based on principles of a collaborative and active learning approach. We focused on the students' exploration and application of the VR-ALM to improve the systems design continuously; that is simulation improvements were made after each trial and are on-going until the end of the project period that will end in March 2018.

1.1 Reflective Questions for Improvement of Learning Design

This paper will describe and discuss the elements of the design of the active learning module that applies virtual reality technologies (VR-ALM) for a continuing education program in Emergency Management in higher education. This paper will discuss and reflect on the following questions:

1. What are the educational challenges that need to be explored and solved in the design of the VR-ALM for training communication tasks for professionals in Emergency Management?
2. What institutional factors play a role in facilitating or hindering the achievement of learning objectives in trialling of the active learning module?
3. What recommendations, based on feedback and experience with the VR-ALM, can be recommended for future designs of VR-ALM such that the system design can better meet the learning needs of EM professionals?

2 Theories of Active Learning and the VR-ALM Design

Emergency Management (EM) requires skills of situation awareness, communication, and decision making. EM responders must make decisions in complex situations often under stressful conditions. There is a need for unified response patterns, thereby ensuring a degree of predictability in the behaviour of participants. However, the situations are characterised by a lack of control of all the parameters involved. The ability for EM responders to deal with uncertainty therefore becomes crucial. The communication learning designs for EM professionals have been historically based on the cognitive perspective of the Naturalistic Decision Making (NDM) approach that is widely recognized in EM literature (Hsu, et. al, 2013; Shen, et. al. 2017; Klein, 2008; Zsambok, 1997; Flin, Slaven & Steward, 1996; Klein, Calderwood& Clinton-Cirocco, 1986; Lipshitz, et.al. 2001). Within the NDM family several related models exist, but in particular the RPD model is based on the cognitive task analysis of firefighters (Lipshitz, et.al. 2001; Klein, 1989). RPD is seen as the most relevant for the EM field. In brief, RPD describes how people make rapid decisions under critical conditions based on previous experience as a repertoire of patterns. When diagnosing the situation, the decision-maker needs to recognize the pattern based on the relevant cues from the environment and then choose the appropriate 'typical' course of action (Klein, 2008). Recent work have confirmed that VR simulation that represents dynamic development of a situation can be a useful tool for assessing the NDM behaviour of the participant and can help the participant to understand their own decisions making process (Lamb, Boosman & Davies, 2015 ; Lamb, Davies, Bowley, & Williams, 2014). Additional research has also shown that, collaborative and active learning has been successfully used in a wide range of educational activities and VR-based environments (Lee, 2009; Merchant et al, 2013). Further, VR-based models are validated approaches for training for real-world mass casualty incident response (Pucher, et al, 2014). The NDM/RPD paradigm was intended to be applied within the VR training scenarios. It is seen as the starting point for the pedagogic model that involved active learning and decision making in the simulated crisis situation.

Activity Theory was selected as the theoretical lens to understand and through reflections make improvements to the active learning system design. Activity Theory draws on Vygotsky's (1978) concept of mediated action and also on Leont'ev's (1978, 1981) Activity Theory. The former's work focuses on mediation at the individual level, while the latter recognises that collective actions are goal-oriented. In the model of Leont'ev (1978) an activity consists of subject, object and tools. Collective actions in the activity system are transforming an object into an outcome. Engeström (1987, 2001) argued that Leont'ev's model does not consider the collaborative nature of actions and therefore developed a model of an activity system. The activity system consists of subject, object, tools, community, rules and division of labour. The activity system allows for multiple perspectives and networks of interacting activity systems. The subjects may have different points of view, and different goals. The interactions between subject and object are mediated by community, rules, and divisions of labour and mediating artefacts (or tools). The outcome can be new patterns of communication or collaboration that result from all the interacting factors of the environment (Engeström, 2007, 2012). Activity Theory helps designers to identify and understand the elements in active learning systems that can facilitate or hinder the achievement of desired learning outcomes.

In our project, the student-subjects were required to communicate and collaborate in multi-disciplinary teams to respond effectively to a simulated crisis situation. The VR platform supports opportunity for reflection by the participating subjects, as it can record and later play-back the actions occurring in the trial runs. The students interact with learning materials in VR-ALM and are required to collaboratively solve problems under critical conditions in a simulated emergency setting. The VR-ALM simulation environment instantiates a learning design that aims to significantly focus on the students' exploration application of course materials that include role cards and the simulated crisis environment. In our research and former related paper we conducted an Active Learning system analysis that explored the significance of activity triangles and interactions of the action and operation elements within the learning context (Prasolova-Førland, Molka-Danielsen, Fominykh, & Lamb, 2017). Activity Theory and that Active Learning analysis were performed after each trial and then informed the iterations of improvements that were made to the design of the learning module. The description of the Active Learning analysis is not repeated in this paper. Rather in this paper we conduct a reflective descriptive analysis of the subject participants and learning community. We seek to gain insight from this project based on feedback from the subjects, and through reflection to gain insight into how to improve the supportive role of the mediating technologies.

3 Description of the Learning Design

In preparedness training for crisis situations, the first responders such as firefighters, police, and health – doctors and paramedics will typically have separate live training exercises. It is not often that the professions come together in multidisciplinary live training exercises. Our ALM-VR project's learning design is therefore a new development for multi-profession training. In the Active Learning Module (ALM), the learning tasks are divided by the professions, but the participants are brought together in the simulated VR environment. The design allows for cross profession training in crisis situations. Also, since communication and interaction within and between teams played a prominent role in the simulator, the learning modules were designed based on socio-cultural theories of learning, in particular, an active learning system based on Activity Theory as we introduced in the prior section. The project created one virtual simulated crisis-scenario for this project, that of an explosion in an industrial warehouse. We simulated an explosion in a random location within the warehouse. There were a number of roles of professions that could be represented or "played" in the simulation. In addition, the roles also had different functions that could be carried out in the simulation. For example, the firefighter could operate the fire hose, while regular workers could take fire extinguishers in the building. The medical professionals could perform triage, address the injured, and transport the injured. We also implemented different radios (communication devices) in the simulation depending on the role. Each profession has its own radio. The leaders from all professions have an additional radio to communicate between each other and with the EM Centre ("Nødnett"). One of the great challenges of the ALM design was to correctly represent lines of communication that would in fact be used in a crisis situation. The model as explained by the EM expert from the UK included several differences from practice in Norway. In the UK the incident leader is a Fire Commander, while alternatively in Norway the role is led by Police.

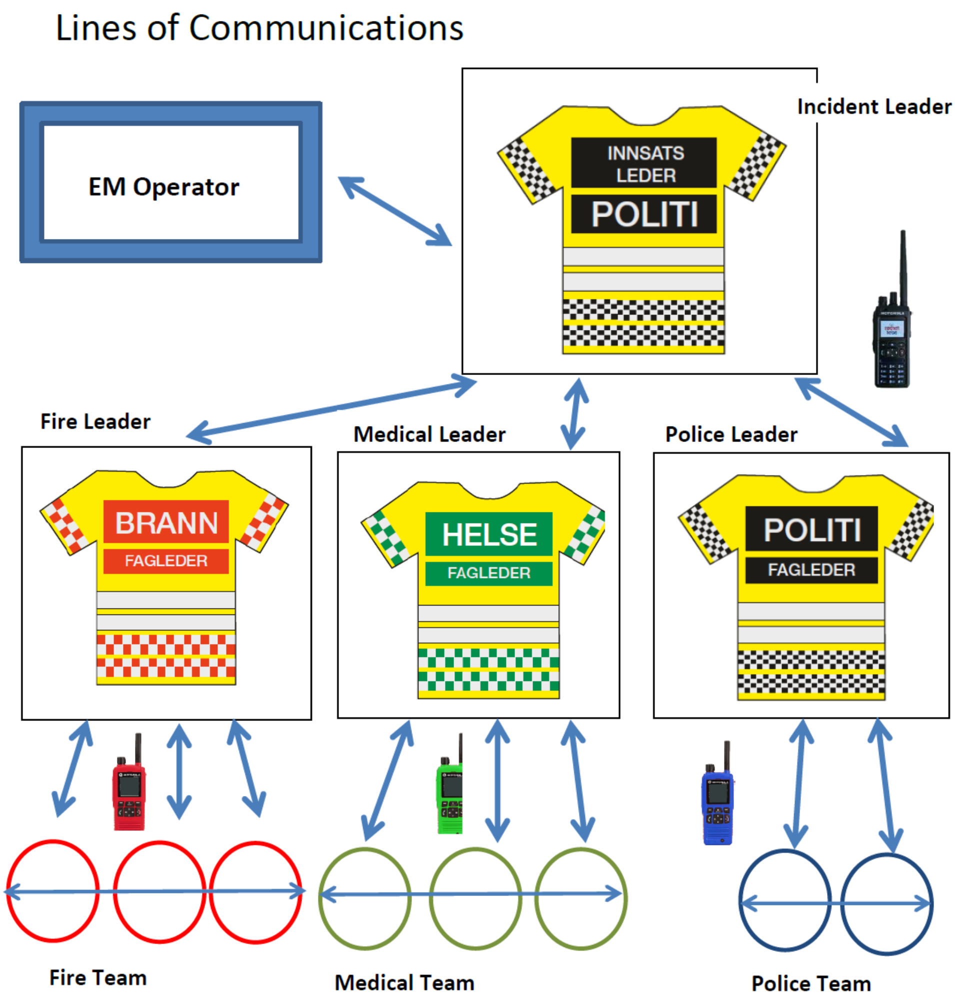

Figure 1. Modelling Lines of Communication

3.1 Learning Materials

To go along with the functionality created for the roles in the simulation, we designed "role cards" (teaching materials) for each of the professions. The role cards explained to the participant which character they were playing, what were their responsibilities as a professional in that role, and what functionality their characters had within the simulated environment. The students were asked to select a role card that represents the profession they intended to play in the trials. An example of a role card is depicted in Figure 4.

Figure 2. VR-ALM trial in April 2016 with high school students

3.2 Trial Procedures – Day One

On each day of the trials, in the first stage of the learning task, the students were: (1) expected to read their role cards, (2) they were given an introduction to the virtual environment, meaning how to move around, how to access their character functions, and how to communicate using voice to the characters in close proximity in the virtual environment and to the characters far away using the radios. This preparation instruction took about one hour.

In the second stage, we ran three runs of the simulation. According to the scenario, the simulation started with an explosion. One participant playing a worker was expected to call in the incident to the EM Centre. The EM-controller would then contact the respective professions: police, fire, and ambulance. The teams of professionals would arrive to the emergency location (virtually), rescue the injured and coordinate between each other and with the local workers. The leader of each profession would communicate with their team on location (without the radio if they were physically nearby), and with the EM-controller for cross team communications (always using the “Nødnett” radio).

In the third stage, the course designers and the EM expert held a reflection session with the students as a form of self-assessment to ask them their impressions of the trials. This was followed up by a survey to ask the students what were their impressions of the VR-ALM as a tool for learning about communication in a crisis situation.

3.3 Trial Participants – Day One

The trials were conducted on two different days. The first trial-day in April 2016 was run with a group of 14 non-professional high school students (videregårende) as seen in Figure 2. The students were all physically seated in one room at HiM**.** Students were grouped in teams of professions (warehouse workers, firefighters, police, health, and one person was the EM-controller). The police, firefighter and health teams seated together could speak to each other without headsets. There were a limited number of headsets on that day. The headsets were used by the team leaders and the EM-controller to communicate with each other using the virtual radio. Because the students did not know their selected "profession" the first two runs were rather unstructured. By the third run of the trial the research team observed that the students grasped their specific tasks, and were able to succeed in a more organized EM response. The students seemed to quickly understand how to move around in the VR simulation.

3.4 Participants and Procedures - Day Two

On the second-trial day in March 2017, we worked with a group of professionals: 4 firefighters who were located at HiM, an EM expert located at HiM, 5 medical students with acute medicine specialization (TRAMS student organization) at NTNU Trondheim and 1 paramedic student at NTNU Trondheim. Several of the professional participants are depicted in Figure 3. Those who participated in this trial knew their profession prior to the trials, and communication took place only by the simulation radios with participants using headsets in the virtually simulated environment. This trial day experienced more problems with the technology because of the large number of simultaneous users accessing the system from different protected networks at the same time. In addition to the 10 students, there were 3 instructors playing roles and 2 technical assistants in Russia playing other needed roles, such as the industry-workers. The simulation-runs filled up server memory and crashed on every second attempt to start it. Therefore, we had to reset the server several times to record three runs. Certain side-effects of software-lag in the simulation environment also were disruptive to the belief in the scenario. For example, stretchers not appearing where they should, etc. The medical students experienced some problems with performing triage as some of the 'patients' disappeared when taken out of the factory, so that not all the triage functionality was tested.

Figure 3. VR-ALM trial in March 2017 with several professional teams in two locations

ROLE CARD FIRE FIGHTER -GROUND LEADER

Inventory/activities:

- Communication equipment/radio to call and receive calls from Alarm central and speak with own fire team
- Communication equipment to communicate with incident commander, EMS Operator, "Incident Leader" (IL), "Medical Leader" (ML), "Police Leader" (PL)
- Fire extinguisher (already in the inventory)
- Freeing trapped persons
- Carrying the injured to safety

Situation description

The purpose of the simulation: to improve understanding of how multidisciplinary teams work at an emergency scene. There are reports of fire and explosion at the gas plant, with several cases of injury and smoke inhalation injury. You are summoned to the incident scene with the team. Your task is to assess the situation, lead the firefighter team at the incident site, collaborate with the incident commander and other team leaders and communicate with the Alarm central. Major actors at the incident site: incident commander, fire-ground commander and EM (Emergency Management) services operator (Incident Leader, Fire, Police and Medical). At the scene you can observe the fire and smoke.

Role description

- You will play the role of the fire-ground leader (Fire Leader). When the game starts, choose one of the 'Firefighter' avatars on the avatar list and then 'Become captain'. You are at the fire station at the beginning of the game.
- You are contacted by the Alarm central when the alarm sounds (the radio icon on the inventory starts blinking. Click on it and then 'push to talk'). Talk about the situation. Then both you and your team will be transported to the scene of the fire by Alarm central operator or you can 'run' there yourself.
- When at the incident site, assess the situation, report to the incident commander. Obtain information about the fire, explosion and injured from the factory team leader. Communicate with other rescue team leaders (medical services and police) in order to coordinate rescue efforts.
- Use fire extinguisher (in inventory) to extinguish the fire. You can also free trapped people and carrying injured people by touching icons in inventory to the designated place for injured.

Suggestions:

- Talk with others using text chat or voice, possibly directly with others in the group. Call Alarm central/receive calls from Alarm central with the 'radio' in the inventory, use 'Push to talk'
- Keep an eye on the 'health' indicator above your avatar! 'Health' will decrease quickly when you are too close to the fire, then you no longer can move and help others!

Figure 4. Role card for the Fire Fighter ground leader

4 Feedback from the Trials of the VR-ALM

As described in the prior section, after each trial run there were discussion and group reflections on what took place in the simulated environment. Students that participated in the April 2016 trials were asked to make a statement regarding what they thought of the VR-ALM. Several of their comments were as follows:

- Liked it, fun, would like to play again
- Learned about communication, how it works

It was also noted that several students wanted simulation to be a part of a safety course within their high school education. It was suggested that the VR-ALM could also be used for EM training in construction workplaces.

Following the March 2017 trials, we also received comments and feedback from the professional participants. The health professionals at NTNU Trondheim had some positive impressions of the VR-ALM. The stated:

- For communication, it is absolutely useful, not so often we get to train with fire and police
- We have these ‘table-top’ exercises where we sit in a room and work on a case…here we could have taken these table top exercises one step further
- For medical students and medical personnel there is value absolutely
- There were some suggestions for improving functionality (triage, communication modalities, bug fixes)

The professional firefighters however, reported that the simulated environment did not represent accurately the real life lines of communication. The study team also surveyed all of the participants. They were asked, "After trying the simulator, do you have a better understanding of how the team members will communicate within teams?" The available responses to this question on a 5-point Likert scale was (not at all, very little, somewhat, considerably, and to a great extent). The responses to this question, although too few for statistical analysis indicated that the inexperienced participants (high school students) felt that the VR-ALM simulation was more beneficial to their understanding about how team members communicate. Ten of them responded "considerably" and four responded, and "to a great extent". The professional firefighters, responded to this question as "not at all" or "very little". The health-professional students gave more positive responses including ("somewhat", "considerably", and "to a great extent").

5 Reflections on the Active Learning Design

The Active Learning Module represented a simulated crisis situation in an industrial warehouse. The physical location and its characteristics were objectified so to create a staged role-play learning exercises. Several learning objectives were identified (e.g., to identify how-to quickly and effectively personnel can evacuate a building or location; to choose the correct actions in the event that injured coworkers are present). The intended learning outcome for the subject participants of the simulation would be to increase skills and confidence in dealing with a variety of possible scenario trajectories. The interaction with the simulated environment took a game-based approach, where different actions are triggered based on the participant's decisions. Many factors need to be represented in the simulation to assure immersion and that the simulation. As such the VR training module captures the dynamic nature of a live incident.

5.1 Educational challenges

This active learning design faced several educational challenges. The primary challenge is that the target subject learners are from a variety of educational backgrounds both professional and non-professional. These groups of users use a different ontological language for describing what they see in the trials, how they communicate with their co-workers and how they respond in the simulated crisis situation. There is a vast difference in knowledge between high school students and professionals. But, there are in addition great differences in knowledge domains between types of professionals (firefighters, medical professionals, etc.). We learned that different learning tasks and different learning goals needed to be prepared depending on the educational background of the learner participants in the ALM.

The second educational challenge is related again to the background of the participants. The professionals have higher expectations of authenticity of the simulated experience to the real life experience. For example, for professionals, if the communication procedures (chain of communications, number of communication channels) are not precisely represented in the simulation as they should be in real life procedures, the professionals then do not rate positively the experience of training in the simulation.

The communication tasks within the professions are seen as isolated. It is only at the top level (communication between the leaders at the communication central) that they communicate across professional groups. At the same time, the medical professionals participating in the trial considered the possibility to train, especially communication, with representatives from other professions very useful as this is something they never experience otherwise.

5.2 Factors Facilitating or Hindering Learning Systems Design

Organisational factors, sometimes referred to as institutional factors in Active Learning theories, can play a significant role in facilitating or hindering the effectiveness of the active learning system. In this study an institutional factor that played a role in the achievement of our goals was the digital infrastructure and personnel to support IT-supportive functions within the participating university organisations. Professional organisations like firefighters might not have the digital infrastructure in place to apply VR tools in EM training. This project was an example of cooperation between higher education and professionals, where resources (knowledge and infrastructure) were drawn from both sectors to contribute to an active learning design. This project needed and received the support of the research partners' IT departments in order to run trials using the VR-ALM. Both universities provided Internet connected PCs in lab rooms, vAcademia software installed on the PCs and headsets for participants. The research team also had an expert understanding of the software and still had to refer to contacts with the developers of vAcademia to schedule and run the trials, and to make improvements to the appearance and functions of simulated artefacts in the VR-ALM. The professional groups could not have easily implemented the VR-ALM without the help of the academic institutions. At the same time, the learning design benefited from the input of the professionals.

A second institutional factor that was important to the achievement of our goals is organizational culture. Within the project the partners were able to adapt the design of the learning task to different student groups that have different educational and digital skills. The project team also had to adapt the advice from an EM expert to be meaningful and accurate to a local student population. In particular, there are differences in regulations and procedures of the EM expert home country (that is the UK), and the new local practice of EM response in Norway. For example, the UK expert indicated that the Firefighter chief is the leader at the crisis site. However, in Norway, the leader at a crisis site is the Chief Police Officer on location. Therefore, depending on the target location/student group, different lines of communication will be needed to be included in the course exercise. Additionally, as a new national Norwegian handbook for health services at an incident point has been recently released with somewhat modified terminology, the role cards need to be updated accordingly.

5.3 Recommendations for Improved Learning Systems Design

Through observations, discussions and feedback with participants in the reflective assessment sessions, the project team were able to identify ways that we think the active learning module could be improved. Several recommendations for future design are as follows:

1. It is important to trial the software with professional groups at an early stage to identify how the simulated environment can be improved to reflect realistic lines of communication and functionality that the professional would normally have in their work role. For example, the firefighter commented that his character was not able to remove a certain obstacle. He further commented that in real life he would have a tool to leverage the heavy object, and so could do something in that situation.
2. The simulated environment should be tested with smaller groups (within profession communication). The VR-ALM seemed to have more potential as a tool for within-team communication. In particular, the cross-team communication seemed only important for the leaders of the teams. So, a separate and distinct exercise for cross team communications could be more helpful to the leadership roles. The design of the communication exercises should to a greater degree be informed by social-cultural theories such as Activity Theory. Creating a separate role-playing exercise with the primary focus on inter- and intra-team communication, with a minimum of practical tasks?
3. Video recordings of trial runs can be used as learning materials. Some of the same lessons can be demonstrated and reflected on by larger groups. This approach has the advantage of not having to train every participant in how to use the simulation before getting trying the learning task. Also, different conflict-scenarios can be prepared and demoed. The recording can be paused, and the students can be asked what to do next. The recording can be re-started and perhaps different recordings can be played back depending on the response of the students.
4. Professionals' times are highly valuable, and it takes much preparation to arrange trial days with them.
5. Creating a set of platform-independent requirements, learning designs, scenarios and exercises to be implemented on a different platform (e.g. Unity)

6 Conclusions and Future Directions

The aim of this project has been to explore the design and trialling of a new resource for Emergency Management education that is based on theories of Active Learning and applies an innovative use of virtual reality technologies (VR). The project developed and tested a prototype active learning module (ALM) in a specialized VR simulation. The ALM has the learning objective to aid Emergency Management and Health professional students in the training of communications in management during a crisis situation. In this paper, we presented a reflective descriptive analysis of the active learning system as interpreted through the theoretical lens of Activity Theory. Activity Theory can help designers of learning systems, and the learners, to understand the way in which collaborate learning tasks are cooperatively realised.

Our reflective analysis gives insight into how to design more supportive mediating technologies. The student subjects in this project interacted with the activity structure from different perspectives and indicated that different designs would facilitate learning for different student groups. This general conclusion is not very surprising; however, more specific feedback was useful to improve this VR-ALM design. In particular, the feedback from the professional participants helped the designers to realise complexities of the real life environment that were not anticipated. For example, after feedback we added an additional radio-system to the simulation. We were informed that there can sometimes be as many as 5 such systems in use. We learned that the professionals focus on the most important lines of communication, and sometime ignore others that do not contribute to the momentary decision making. In the simulation, we also experienced technical problems with the VR-server for runs that have many simultaneous users (e.g. 15). It is difficult therefore to include the sometimes greater number of persons that are involved in incidents. We discovered limitations of our approach that is we could not represent the complete command chain in the simulation, as we could not support more simultaneous users.

Several broader implications of this research are the possible drawbacks to applying VR in EM training that we note as: (1) in comparison to workplace training, VR simulations offer no training of physical skills and are therefore less realistic by definition; (2) in comparison to the current classroom education (e.g. lectures), VR simulations can be more expensive; and (3) technologies and user interfaces are new and unstable. This can create a sharp learning curve for users that can make some decide against applying VR in EM training.

Despite these drawbacks, new VR technologies show potential to contribute to the immersive effect of the VR simulation. Based on this reflective analysis, we conclude that VR can contribute to EM training. Furthermore, other new technologies, such as virtual reality (VR) and augmented reality (AR) will contribute to improving the learner's experience. VR headsets such as Oculus Rift can provide an accurate and high-fidelity replication of cues from real-life emergency situations leading to more immersive experiences. AR tools (such as head mounted displays and smart glasses) and AR training components (tracked imagery within the simulation) could help the learner to form of acquired “repertoire of patterns” at a much faster rate than traditional experience building in the field. Research in both VR and AR will contribute to improving participants' experiences by allowing the development of more realistic training simulations with accurate replication of real-life emergency situations that will give greater opportunity for effective collaborative training for EM professionals.

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