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Simulation-based training in the use of the EU-SENSE CBRN reconnaissance device: a case study

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Abstract

The aim of the article is to build up qualitative evidence that CBRN training, which requires quick and prompt reactions from first responders, should involve simulation. The authors rely on a case study, the European Sensor System for CBRN Applications - EU-SENSE project, which has to provide an adaptable and multipurpose hazard detection solution for enhancing situational awareness. A dedicated training mode on how to use the device by CBRN practitioners assumes that life-threatening substances are present in a real-life operation. Therefore, in order to provide lifelike experiences in a controlled environment, a simulation-based activities can be proposed. The analysis of CBRN training requirements and sample hypothetical scenarios, which complement the case study, proves that CBRN mission-specific training requires the design of a range of simulation-based activities that help learners acquire safe behavioural competences and at the same time examine their performance. They will be also conducive to developing decision-making and communication skills and improving situational awareness. In a contaminated environment, these skills are necessary for survival. This study contributes to the growing body of research on CBRN training concerning newly developed devices, which enhance the work of CBRN practitioners.

Keywords: simulation-based training; CBRN reconnaissance system; chemical contamination; chemical sensor

1. Introduction

Knowing and understanding a specific crisis situation is the key to successful preparation for a CBRN incident. Familiarity with the situation can be achieved through systematic training that “involves preserving and improving the ability of military individuals, staffs and forces to perform sound military operations. It complements education (as disseminating knowledge through formal or informal study), individual and collective training as well as exercises” (NATO, 2010).

The accidental or deliberate misuse of toxic substances requires external support from military or civilian entities (P. Maciejewski, R. Pich, & J. Wrzesiński, 2010; P Maciejewski, R Pich, & J Wrzesiński, 2010; Maciejewski & Robak, 2008). Dedicated, specialised teams for dealing with crisis situations are considered first responders, and the first action they take is to identify the nature of the threat. In this phase, the proper use of the CBRN detection system (or wider: the reconnaissance system), plays a vital role. A variety number of potentially hazardous agents may be present at a scene, including substances that are normally perceived as safe, for example fertilizers (Wrzesiński, Kołaczkowski, Maciejewski, Pich, & Nagrodzka, 2011, 2012). First responders learn how to operate a specific device in order to detect, identify and confirm the presence of any hazardous substances and then report their findings to specialized analytical centres. This information is ultimately retrieved by command structures. This typical scenario, based on a systemic approach, can be carried out in the form of a simulation, that is, an imitation of a real situation or process. As a didactic method, simulation engages learners in the designed situation in an active way (Akselbo, Olufsen, Ingebrigtsen, & Aune, 2019; Maciejewski, 2017; Moxley, Maturin, & Habtezgi, 2021).

This article aims to prove that the CBRN training on state-of-the-art solutions, should widely employ a simulation method. This method allows learners for acting in a hostile, contaminated environment and acquiring relevant competences (including hard and soft skills).

The introductory section (Section 1) explores the issue of simulation-based training. It provides examples from industry and focuses on publications analysis from Scopus database. Section 2 explores the case study – the European Sensor System for CBRN Applications – EU-SENSE project, which aims to develop a unique chemical detection device and deliver a tailored training on its use. This section explains training requirements as well as introduces hypothetical scenarios from a Subject Matter Expert. Section 3 provides qualitative evidence that, regarding soft and hard skills acquired in a hostile environment, simulation is the most appropriate method for CBRN training involving state-of-the-art devices. The section also discusses specific aspects of building of an optimal simulation scenario. The perspectives of both the first responders and those who gather and interpret the resulting data are taken into account. In the conclusions (Section 4) we state that due to numerous advantages, a CBRN simulation-based training for newly developed solutions is highly recommended. We also outline possibilities for maximising learning opportunities in this field.

1.1. Simulation as a didactic method

Simulation replicates reality or closely approximates a real system (Kurup, Matei, & Ray, 2017). Applied in training, it allows for immersion in a situation, "reflection, feedback, and practice minus the risks inherent in a similar real-life" situation (Binotti et al., 2019). It also fosters personal competences such as decision-making and leadership (Orr, 2020). There are many types of simulations that can be used in didactic activities; for instance, live simulations, "where users are in a real environment using real equipment whose effects are simulated"; virtual simulations, where "the user is immersed to some degree in an environment which represents the real one"; and constructive simulations, where both the equipment and system operators are simulated. In this last case, user interaction may be an element of the training, but is limited to the exercise of broad control over tactics/movement "and this does not involve using simulated controls representing the real systems" (Smith & Steel, 2000). Also worthy of mention are in-situ simulations, which can be used to improve reliability and safety, especially in areas of high risk and in high-stress environments (Kurup et al., 2017). Such exercises can be performed using hands-on equipment and on-site infrastructure. It should be emphasized that NATO has published a standardisation document, according to which modelling and simulation should conform to life cycle standards, including interoperability (on the technical, syntactical, semantic, and pragmatic levels) - which is the ability to act together coherently, effectively and efficiently in order to achieve allied tactical, operational and strategic objectives (NATO, 2018, p. 33). The scope of practice can range from coalition training to experimentation. In the case of joint multinational exercises, the NATO recommendations should be taken into account.

1.2. Simulation-based training for the state-of-the-art CBRN solutions

Simulations are often used in the CBRN training, what can be illustrated with examples from the industry and confirmed by literature search. New solutions from industry are designed for detection, or mapping the contaminated area, simulations. The examples are the Saab Gamer CBRN interface integrating Saab's Gamer live firing capability with Argon's PlumeSIM technology (Pike, 2017, 2020); hazmat (hazardous material) training simulator products and services (argonelectronics.com, n.d.); real-time simulation of CBRN ground and airborne contamination (bruhn-newtech.com, n.d.); the Augmented REality Sandtable (ARES), used the for the development various map overlays, evaluation of proposed strategies, and reporting the results to the course instructor (Abich et al., 2018). Apart from the examples from industry, literature reports also show interest in the subject of simulation in CBRN training. The search for publications (2017-2021) in Scopus database with the use of Boolean operators ALL ("CBRN" OR "CBRNe" AND "simulat*"), indicated that the interest in the CBRN keywords combined with the "simulation" (the added asterisk replaces multiple characters anywhere in a word) is growing. For the year 2017 there were 79 publications, consequently, for 2018 - 99, 2019 - 98, 2020 - 125, and 2021 – 74. It can be implied that simulation-based training is perceived as one of the most effective didactic methods in this area. In this study our aim is to reveal new qualitative evidence for this trend altogether with outlining specific advantages of a simulation-based training, which apply to the use of the EU-SENSE CBRN reconnaissance device, in particular.

2. Materials and Methods

The materials used in the present analysis comprise documents related to the EU-SENSE project, particularly the relevant training mode requirements and assumptions and the NATO framework for CBRN training, as well as hypothetical scenarios that can be applied in the training. The research method is an analysis of a case study, that of the EU Sense Project, and specifically the use of simulation in CBRN training. Although case studies are not applicable to data collection, in the social sciences they are valuable when formulating in-depth explanations of specific states, situations, or behaviours (Hyett, Kenny, & Dickson-Swift, 2014). In this research, the case study chosen provides understanding and insight into the object of interest, and it was for this reason that the authors took an interpretive approach to a qualitative case study. Training scenarios from a Subject Matter Expert (SME) complement the case study and reveal the specificity of the training.

2.1. EU-SENSE - European Sensor System for CBRN Applications project – a case study

CBRN is attracting increasing attention from scholars and industry, and this has resulted in the creation of specific frameworks and programmes that allow for the development of novel tools specifically for CBRN defence. CBRN research projects have been developed within: the Community Research and Development Information Service - CORDIS, EU CBRN Centres of Excellence (CoE) Projects, the European Reference Network for Critical Infrastructure Protection, and Interregional cooperation - INTERREG, (Encircle, n.d.). The EU-SENSE - European Sensor System for CBRN Applications project (2018-2021), funded from the European Union's Horizon 2020 research and innovation programme, is focused on improving the work of CBRN first responders by delivering a novel chemical detection tool. The tool will be based on machine learning algorithms that help to reduce environmental noise. The project consortium consists of universities, private companies and research agencies: ITTI Sp. z. o.o. – Poland, the Netherlands Organisation for Applied Scientific Research (TNO), the Swedish Defence Research Agency (FOI), the Norwegian Defence Research Establishment (FFI), the Technisch-Mathematische Studiengesellschaft mbh (TMS) - Germany, the Main School of Fire Service (SGSP) – Poland, Airsense Analytics (AS) – Germany, the University of Warsaw (UW) – Poland, and the Police Service of Northern Ireland (PSNI). All the consortium's efforts are aimed at improving the situational awareness of CBRNe practitioners, not only by development of novel sensor nodes, but also by proposing effective modes of training (M. Dobrowolska-Opala, Gudzbeler, G., 2019; EU-SENSE, 2020), such as simulation. It should be added that the novelty of the training relies on synthetic data defined within the pre-defined scenarios. The synthetic data will be used for constructing machine learning algorithms to build a realistic substance distribution within the environment. This will also make allowances for naturally existing background noise (clutter) (Encircle, n.d.).

2.2. Training for CBRN practitioners

2.2.1. General requirements and assumptions for the EU-SENSE training mode

CBRN training standards apply to non-specialists, including civilians, medical personnel, commanders and their staff, and CBRN specialists. Apart from knowledge and social competences, training participants should possess both CBRN survival skills and CBRN operating skills (NATO, 2010). In the EU-SENSE project, learners are expected to know how the sensor modes work, and how to use the tool in the field.
Three requirements for the EU-SENSE training mode were formulated on the basis of qualitative research (Sellevåg, 2018). These are: dedicated packages, the length of the training, and guidance on the deployment of chemical sensor nodes (M. Dobrowolska-Opala, Gudzbeler, & Misiuk, 2019). Dedicated training packages must focus on various levels of end users in terms of their function, roles, and area of expertise. Training length is defined by factors such as the sensor arrangement (for instance, protective clothes can contain a net of sensors), environmental conditions and the method of training. Guidance on the deployment of chemical sensor nodes concerns the specific scenario realised to be run through during a training activity. The pattern used relates to learning experience design (LX design). All the requirements focus primarily on the user experience (UX), which is crucial when creating a tailored training. Based on the above three categories, the main assumptions for the EU SENSE training mode were developed:

- the module will be based on an integrated system built during the EU-SENSE project,
- it will contain selected functions of the operating system only,
- it will be fed with artificial data defined by a given training scenario (M. Dobrowolska-Opala et al., 2019).

A SWOT analysis of the training module proposal revealed that, among the numerous factors present, the training may involve actors from different tactical and strategic levels (a strength); a lack of artificial data may hinder the reliability of the tools (a weakness); the experiences related to the training mode can contribute to training methodologies applied to crisis management exercises (an opportunity); and there is uncertainty related to the use of the sensor in practice (a threat). All the factors identified are taken into account and analysed within the project's key processes, i.e. its progress & quality,

risk management, and change and knowledge management processes.
The aforementioned requirements and assumptions resulting from qualitative data from the project consortium can be treated as a major limitation for the project research activities.

2.2.2. Chemical agents training conditions from NATO requirements

According to a NATO/Partnership for Peace unclassified publication concerning a military education, training, and evaluation standard (ATP 3.8.1), training on combating chemical agents should focus on the following conditions:

a. Realism: in the training, detectors should react in a completely realistic manner. The exercise dealing with real agents, and reliance on individual protection equipment (IPE) to prevent injury further increases the realism of the exercise.

b. Effectiveness: when a learner knows that the agent is only a simulant, the effectiveness of the training may be reduced.

c. Skill acquisition. The training should prepare for more learning experiences in the field.

d. Realistic testing of stress management. Too extreme a level of stress can have profound effects on cognitive and motor abilities and will impair communication.

e. Improved confidence on CBRN equipment. Repetitions of activities help learners gain confidence in their performance.

f. Testing the effectiveness of CBRN defence procedures (NATO, 2010).

2.2.3. CBRN simulation scenario development

The development of a CBRN training scenario can draw on the Analysis, Design, Development, Implementation, and Evaluation (ADDIE) Model (Gawlik-Kobylinska, 2018). In the analysis phase, the objectives are clarified on the basis of a training needs analysis document. The design phase involves defining the core scenario elements, relying on both didactic and technological solutions. In the case of the EU-SENSE training scenario, the design phase might include the following challenges:
- the arrangement and deployment of detection and identification instruments;
- detection or identification route planning;
- the correct preparation and configuration of CBRN hazardous materials (HAZMAT) detection and identification instruments;
- the ability to read and interpret data provided by the device;
- the ability to read and interpret data correctly while wearing personal protection equipment;
- the ability to read and interpret data correctly in daylight and at night;
- the management of unusual crisis situations.

In the development phase, the scenario is prepared. This is then implemented with a specific system. The evaluation phase concerns both the didactic and technological aspects, and engages all project stakeholders. The ADDIE model is iterative, and can be interspersed with agile methods of instructional design.

Apart from methodological issues, the subject of the scenario should focus on detection, prompt identification, and monitoring in various environments. The activities designed should focus on the cognitive, emotional, social and psychomotor aspects of learning (Gawlik-Kobylińska, 2018), where cognitive elements refer to memory and information processing; emotional to motivation and arousal during the performance of a didactic activity; social to interactions between actors; and psychomotor to the physical activities of a learner or a group.

Three sample hypothetical scenarios from a Subject Matter Expert: an attack at the airport, a chemical substance release on the ground, and an attack on governmental infrastructure, can be taken into account when creating a simulation. Each case concerns different types of agents and involves different environmental conditions. It should be emphasised that the scenarios concern first-response activities. This means that they are tactical activities, all of which can be performed as a live, virtual, or constructive simulation.

Scenario 1 – at the airport

Leaking fluid from one of the in-flight supply containers is found at the security checkpoint in the restricted area during a security control carried out by the Airport Security Service. An employee from a supply company begins to show symptoms of shortness of breath. The shift commander of the Airport Security Service orders the evacuation of the security checkpoint and blocks access to it. At the same time, the Chief of the Air Force Crisis Staff is notified of the fact of a crisis situation. Special services are alerted the rescue and reconnaissance team arrives at the scene of the chemical alarm. During the safety check, an increased chemical concentration, harmful to human health and life, is detected. An emergency zone is designated, and in the location of the incident the chemical reconnaissance services locate the source of the chemical hazard and identify the chemical compounds involved. The services secure the place where the suspicious object is located, together with on-board supplies, by designating appropriate safety zones. After performing these activities and securing the area, specialist services carry out subsequent tasks in accordance with the procedures adopted in the face of such a threat.

Scenario 2 – at the ground

The police receive a report that a body has been found in a nearby forest. Information is found nearby that the area has been contaminated with chemicals. Plastic bottles are visible at the scene. Rescue and chemical services are called in. First, the rescuers secure the scene, designate a safe area, and then proceed to detect and identify a dangerous chemical substance that could have been used by the deceased agent, or possibly by third parties. For this purpose, equipment for the detection and identification of chemical hazards is used.

Scenario 3 – an attack on government infrastructure by an unmanned aerial vehicle that may contain hazardous chemicals

After obtaining information about an act of unlawful interference in an area of government infrastructure by an unknown unmanned aerial vehicle, as well as an alarm from signaling devices on increased chemical activity in the restricted area of government facilities, the facility dispatcher announces an alert phase in connection with a suspected spraying of hazardous chemicals. The crisis team responsible for the organisation, implementation and management of rescue services calls for specialized chemical services with specialised equipment for the detection, identification, and neutralisation of the chemical threat. The reconnaissance device collects and analyses incoming data from the field.

The scenarios describe situations where a hazardous substance was released. They aim at triggering immediate action to achieve chemical decontamination. All operations are performed in hazardous environments (including open air space or critical infrastructure). The need for a quick response causes stress and anxiety. Assessing the situation assessment, taking prompt decisions and communicating effectively are the crucial skills to be developed or improved.

3. Results and Discussion

The analysis of the EU-SENSE case study involving the training requirements, NATO requirements as well as scenarios from an SME, indicate that:

1) CBRN mission-specific training requires the design of intrinsic learning experiences, thanks to which a mixture of hard and soft competences are exercised in specific conditions. The hard skills involve personal protection procedures, detection instruments deployment, route planning, device configuration, data reading and interpretation; the soft skills include crisis situation management, in particular prompt decision-making, effective communication, and improved situational awareness. Learners have to react, interact, and learn from their mistakes to acquire safe behavioural competences.

2) During a simulation, learners' performance can be monitored, controlled, corrected, and evaluated. Scenario-based incidents can be repeated, which enables instructors to effectively evaluate simulated performance and correct improper habits during performance (Maciejewski, Robak, & Młynarczyk, 2015).

3) As a real mission is fast-paced and requires energy and stamina from all actors, who must work under great pressure from a range of risks and uncertainty (Domalewska, 2019), simulation-based training seems to be the most appropriate method for achieving the intended didactic outcomes, especially when the training has to prepare participants for operations in a hostile (contaminated) environment.

4) A digital environment can be used for the whole training process. Simulations can then rely on synthetic data pr-edefined by scenarios. This is one of the EU-SENSE project assumptions thanks to which simulation activities can be conducted in safe conditions. And since simulations can also be implemented in online learning (Gawlik-Kobylińska, Domalewska & Maciejewski, 2021), the learning experience is maximized.

Overall, these qualitative results indicate that simulation helps trainees to gain safe behavioural competences and helps teachers examine learners' performance in a simulated hostile environment. It can be noted as well that the effective creation of a simulation-based scenario is related to the training needs analysis, the definition, development and implementation of the didactic and technical aspects of the training design, and finally, the evaluation of the entire training. A scenario design that focuses on cognitive, emotional, social and psychomotor elements makes learning more attractive and effective. As can be observed, the CBRN scenarios involve motor skills. Examples from the literature confirm that simulation is specifically conducive to the acquisition of psychomotor skills (Hubal, 2016; Ross, 2012). Training designers, therefore, should focus on a proper environmental arrangement of objects and an intuitive use of didactic aids, which, in the case of the EU-SENSE project, is a CBRN reconnaissance device based on a novel network of sensors.

4. Conclusions

Simulation as a didactic method is a viable form of CBRN training, particularly the one which aims at familiarization with a state-of-the-art devices. It fosters soft and hard skills of learners who operate in a hostile environments. Therefore, it should be highly recommended for instructors and training designers. However, specific conditions, such as instructional model implementation (ADDIE) and a balanced approach to scenario design (cognitive, emotional, social, psychomotor dimensions of learning), should be taken into account.

Simulation can be supported with other methods and tools to maximise learning opportunities, for instance with games (Newsome, 2018; Sottilare, 2018). In the literature, we find that simulation-based training can be interspersed with debriefing (Fanning & Gaba, 2007; Fung et al., 2015) or instructor-led interventions in the form of instructor-modelled learning (Fung et al., 2015; LeFlore & Anderson, 2009). Such interventions can also significantly enhance the learning process. Moreover, when training is conducted in a synthetic environment, simulation provides a 'painless' way for participants to learn from their mistakes (Maciejewski, 2016). This is a highly effective way of transferring key skills related to CBRN defence and maintaining readiness to perform tasks while meeting the highest safety standards. The use of artificial intelligence in the learning environment also fosters learning opportunities. A specifically designed algorithm can provide personalised learning experiences and is conducive to acquiring key competences.

CBRN training is often performed in international teams. When multinational teams are engaged in simulated procedures, the success of the training depends on all participants functioning together as a team. But such training can only be effective where there is a shared understanding of the standards adopted. This means that all the participant states must have a clear and common understanding of how to command, as well as how to execute, CBRN tasks (NATO, 2010).

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References

Abich, J., Eudy, M., Murphy, J., Garneau, C., Raby, Y., & Amburn, C. (2018). Use of the augmented reality sandtable (ares) to enhance army cbrn training. In *HCI International 2018 – Posters' Extended Abstracts* (pp. 223-230).

Akselbo, I., Olufsen, V., Ingebrigtsen, O., & Aune, I. (2019). Simulation as a learning method in public health nurse education. *Public Health Nurs, 36*(2), 226-232. doi:10.1111/phn.12560

argonelectronics.com. (n.d.). CBRNe / hazmat training simulator products and services. Retrieved from https://www.argonelectronics.com/cbrn-hazmat-training-simulator-product

Binotti, M., Genoni, G., Rizzollo, S., De Luca, M., Carenzo, L., Monzani, A., & Ingrassia, P. L. (2019). Simulation-based medical training for paediatric residents in italy: A nationwide survey. *BMC Med Educ, 19*(1), 161. doi:10.1186/s12909-019-1581-3

bruhn-newtech.com. (n.d.). CBRN-Sim. Real-time simulation of CBRN ground and airborne contamination. Retrieved from https://bruhn-newtech.com/wp-content/uploads/2018/08/bruhn-newtech-cbrn-sim.pdf

Dobrowolska-Opala, M., Gudzbeler, G., & Misiuk, A. (2019). *D3.5 training and simulation mode concept*. Retrieved from https://cordis.europa.eu/project/id/787031/results/pl

Dobrowolska-Opala, M., Gudzbeler, G. (2019). *European Sensor System for CBRN Applications*. Paper presented at the The 9th International Defence and Homeland Security Simulation Workshop, Lisbon, Portugal. http://www.msc-les.org/proceedings/dhss/2019/DHSS 2019.pdf

Domalewska, D. (2019). The role of social media in emergency management during the 2019 flood in Poland. *Security and Defence Quarterly, 27*(5), 32-43. doi:https://orcid.org/0000-0001-788-1591

Encircle. (n.d.). CBRNe projects. Retrieved from http://encircle-cbrn.eu/related-projects-2/cbrne-projects/

EU-SENSE. (2020, 17 Jan 2020). EU-SENSE innovations featured in emergency services times. Retrieved from https://eu-sense.eu/eu-sense-innovations-featured-in-emergency-services-times/

Fanning, R. M., & Gaba, D. M. (2007). The role of debriefing in simulation-based learning. *Simul Healthc*, 2(2), 115-125. doi:10.1097/SIH.0b013e3180315539

Fung, L., Boet, S., Bould, M. D., Qosa, H., Perrier, L., Tricco, A., Tavares, W., Reeves, S. (2015). Impact of crisis resource management simulation-based training for interprofessional and interdisciplinary teams: A systematic review. *J Interprof Care, 29*(5), 433-444. doi:10.3109/13561820.2015.1017555

Gawlik-Kobylinska, M. (2018). Reconciling ADDIE and agile instructional design models—case study. *New Trends and Issues Proceedings on Humanities and Social Sciences, 5*(3), 14-21. doi:10.18844/prosoc.v5i3.3906

Gawlik-Kobylińska, M. (2018). The four-dimensional instructional design approach in the perspective of human - computer interactions. In N. Petkov, N. Strisciuglio, C.M. Travieso-González (Eds.), *Frontiers in Artificial Intelligence and Applications. Applications of Intelligent Systems: Proceedings of the 1st International APPIS Conference* (Vol. 310) (pp. 146-156). Amsterdam, Netherlands: IOS Press.

Hubal, R. (2016). Design and usability of military maintenance skills simulation training systems. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting, 49*(24), 2110-2113. doi:10.1177/154193120504902409

Hyett, N., Kenny, A., & Dickson-Swift, V. (2014). Methodology or method? A critical review of qualitative case study reports. *Int J Qual Stud Health Well-being, 9*, 23606. doi:10.3402/qhw.v9.23606

Kurup, V., Matei, V., & Ray, J. (2017). Role of in-situ simulation for training in healthcare: Opportunities and challenges. *Curr Opin Anaesthesiol, 30*(6), 755-760. doi:10.1097/ACO.0000000000000514

LeFlore, J. L., & Anderson, M. (2009). Alternative educational models for interdisciplinary student teams. *Simul Healthc, 4*(3), 135-142. doi:10.1097/SIH.0b013e318196f839

Maciejewski, P. (2016). Design and implementation of e-learning: The case of weapons of mass destruction defence training. *Zeszyty Naukowe AON, 4*(105), 53-65.

Maciejewski, P. (2017). Ict tools in cbrn troops' education and training. *Journal of Science of the Gen. Tadeusz Kosciuszko Military Academy of Land Forces, 186*(4), 121-137. doi:10.5604/01.3001.0010.7223

Maciejewski, P., Pich, R., & Wrzesiński, J. (2010). Specjalistyczne grupy ratownictwa chemiczno-ekologicznego państwowej straży pożarnej-zadania i wyposażenie. *Zeszyty Naukowe/Wyższa Szkoła Oficerska Wojsk Lądowych im. gen. T. Kościuszki*, 150-160.

Maciejewski, P., Pich, R., & Wrzesiński, J. (2010). Specjalistyczne grupy ratownictwa chemiczno-ekologicznego państwowej straży pożarnej-zadania i wyposażenie-część ii. *Zeszyty Naukowe/Wyższa Szkoła Oficerska Wojsk Lądowych im. gen. T. Kościuszki*, 217-241.

Maciejewski, P., & Robak, W. (2008). Mobilne laboratorium obrony przed bronią masowego rażenia-nowy element systemu wykrywania skażeń. *Zeszyty Naukowe/Wyższa Szkoła Oficerska Wojsk Lądowych im. gen. T. Kościuszki*, 104-112.

Maciejewski, P., Robak, W., & Młynarczyk, M. (2015). Indywidualne środki ochrony przed skażeniami w wojsku polskim. *BITP*(37, Issue 1), 107-118.

Moxley, E., Maturin, L. J., & Habtezgi, D. (2021). A lesson involving nursing management of diabetes care: Incorporating simulation in didactic instruction to prepare students for entry-level practice. *Teaching and Learning in Nursing, 16*(1), 10-15. doi:10.1016/j.teln.2020.09.007

NATO. (2010). NATO - ATP-3.8.1 - CBRN defence on operations *Vol. I.*

NATO. (2018). NATO Standard - AMSP-01. NATO modelling and simulation standards profile. In (Edition D Version 1 ed.): NATO Standarization Office.

Newsome, E., Militello, L., & Ramachandran, S. (2018). *Stratagems: Embedding cognitive training in game-based environments*. Paper presented at the Proceedings of the International Defence and Homeland Security Simulation Workshop 2018. https://www.msc-les.org/proceedings/dhss/2018/DHSS2018.pdf

Orr, M. T. (2020). Reflections on active learning in leadership development. *Journal of Research on Leadership Education, 15*(3), 227-234. doi:10.1177/1942775120936305

Pike, S. (2017). Marriage of SAAB training systems gamer and argon's CBRN plumeSIM. *CBRN / HazMat Training Blog.* Retrieved from https://www.argonelectronics.com/blog/marriage-of-saab-training-systems-gamer-and-argons-cbrn-plumesim

Pike, S. (2020). What are the key innovations transforming cbrne simulator training? Retrieved from https://hazmatmag.com/2020/06/what-are-the-key-innovations-transforming-cbrne-simulator-training/

Ross, J. G. (2012). Simulation and psychomotor skill acquisition: A review of the literature. *Clinical Simulation in Nursing, 8*(9), e429-e435. doi:10.1016/j.ecns.2011.04.004

Sellevåg, S. R. (2018). *D2.2 user requirements*. Retrieved from https://cordis.europa.eu/project/id/787031/results/pl

Smith, J. D., & Steel, J. (2000). *The use of virtual simulation for dismounted infantry training*. Paper presented at the The Second NATO Modelling and Simulation Conference, Shrivenham, UK.

Sottilare, R. A. (2018). *A hybrid machine learning approach to automated scenario generation (asg) to support adaptive instruction in virtual simulations and games*. Paper presented at the Proceedings of the International Defence and Homeland Security Simulation Workshop 2018 https://www.msc-les.org/proceedings/dhss/2018/DHSS2018.pdf

Wrzesiński, J., Kołaczkowski, A., Maciejewski, P., Pich, R., & Nagrodzka, M. (2011). Studium zagrożeń wybuchowych powodowanych spontanicznym rozkładem termicznym emulsji azotanu (v) amonu. Cz. 1, badania kalorymetryczne. *Przemysł Chemiczny*, *90*, 2106-2110.

Wrzesiński, J., Kołaczkowski, A., Maciejewski, P., Pich, R., & Nagrodzka, M. (2012). Studium zagrożeń wybuchowych powodowanych spontanicznym rozkładem termicznym emulsji azotanu (v) amonu. Cz. 2, kinetyka procesu rozkładu termicznego, szacowanie ryzyka wybuchu cieplnego. *Przemysł Chemiczny*, *91*(2), 173-177.