Simulation-based Learning in Aviation Management Studies using SIMIO Software

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Abstract. Focus on digital technologies is one of the strategic priorities in aviation. Although simulation-based learning techniques have been widely applied in the training of aviation pilots or communications, navigation, and surveillance (CNS) students, less attention has been paid to the use of modeled simulations in aviation management (AM) training.

Simulation-based learning tools and strategies can be applied in designing structured learning experiences, providing opportunities to practice skills and implement different types of instruments to support effective learning. Previous studies about AM simulations have provided various examples of how to apply experimental controls to test and validate new AM concepts.

This paper presents the learning journey of implementing SIMIO software (hereinafter platform) in the teaching of aviation industry managers at the Estonian Aviation Academy. The platform was developed jointly with the Arctic University of Norway in Tromso.

We examined the adaptation and use of SIMIO-based simulations as a platform for training and learning for undergraduate students. The paper includes an overview and analysis of theoretical concepts on simulation-based learning (SBL). The study methodology is defined as an action research project, supporting the implementation of smart digital technologies in aviation management training in higher education. In conclusion, the main outcomes of the project, students' feedback, and assessed obtained teaching outcomes are highlighted. Additionally, there are some tracks for further improvements in simulation-based learning methods.

Introduction

Aviation is a complex industry frequently facing extraordinary situations, such as the COVID-19 pandemic or changes in flight intensity, necessitating swift and efficient solutions to maintain functionality and safety. The adoption of new innovative technologies in aviation heavily relies on digital solutions, requiring personnel to possess extensive digital skills. In contemporary aviation education, various digital simulations are extensively used to replicate real-world scenarios. Simulation-based learning tools and strategies are instrumental in designing structured learning experiences, offering opportunities to practice skills and implement different types of scaffolding to support effective learning (Lateef, 2010; Chernikova et al., 2020).

While simulation-based learning techniques have been widely applied in pilot training, their use in aviation management training has received less attention. SIMIO simulation software offers a robust platform for visualizing processes and provides a true object-based 3D modeling environment, facilitating the construction of models in a single step. It grants fast access to a vast library of freely available 3D symbols, enhancing model realism (Simio, 2021). This capability has led to SIMIO's successful application in various fields, including engineering, healthcare, and aerospace, and its growing use in simulation-based learning for aviation management (Dehghanimohammadabadi & Keyser, 2017; Duca & Attaianese, 2012).

The current study addresses the discrepancy between the comprehensive knowledge and skills students should acquire about aviation's interconnected components and the actual learning outcomes, particularly regarding skills needed to work with advanced technological solutions. There is a lack of synthesized results on the role of different simulation features and instructional support (scaffolding) in effectively supporting learners (Chernikova et al., 2020).

Previous studies on aviation management (AM) simulations have highlighted numerous possibilities for applying experimental controls and testing new concepts (Blickensderfer, Liu & Hernandez, 2005; Heesbeen, Hoekstra & Clari, 2003).

Using SIMIO software in AM simulations allows the creation of an authentic learning environment that simplifies technical processes while considering students' prior knowledge and experience. This paper aims to present the learning process of implementing simulation-based learning using SIMIO software to teach future aviation managers. The courses cover airport operations, ground handling procedures, flight planning, and airline financial projections. Simulations help students understand the complexity of aviation management processes by modeling them and providing additional insights into the real world.

The paper outlines the specific action research process, beginning with a literature review on simulation-based learning activities, followed by a detailed description of the employed methodology. Subsequent sections present the research phases, discuss the results, and highlight the main findings.

1 Simulation-based Learning Competencies

A simulation is an activity designed to mimic a real-world scenario. Cook et al. (2013) stated that simulation is an "educational tool or device with which the learner physically interacts to mimic real life". This type of learning experience allows users to engage with situations they might encounter in their actual jobs (Designing Digitally, 2017).

Previous studies have demonstrated that virtual simulations are among the most effective means to facilitate learning (Statti, 2021; Chernikova et al., 2020; Duca & Attaianese, 2012). Simulations provide an authentic learning environment that contributes to learner satisfaction (Lohman et al., 2019). They enhance employability skills such as technical, functional, problem-solving, decision-making, and communication competencies (Lateef, 2010). Additionally, simulation-based learning (SBL) in aviation management (AM) offers benefits like lower operating costs, increased safety, and decreased training time in operational environments (Blickensderfer, Liu & Hernandez, 2005). Corrigan et al. (2015) highlighted that simulations and serious games can support collaborative learning and enhanced communication in the airport collaborative decision-making process.

Competencies acquired through SBL are crucial for the transfer of skills into everyday operational practice. Several motivational components support simulation-based learning and gamification. First is autonomy, where learners in "gameful design" feel they have choices and ownership over their learning. The second is mastery, involving becoming skilled in a particular area. Third is purpose and meaningfulness, where it is vital that learners are presented with relevant and authentic content. Fourth is relatedness or the social aspect of gamification, where learners benefit from interactions with co-learners, stay engaged, and feel part of a larger learning community (Designing Digitally, 2017).

2 Methodology

The study was based on action research, supporting the implementation of simulation-based learning in the air management training study track. The action-based research was conducted during 2020-21 by two organizations: the Estonian Aviation Academy (EAVA) and the Arctic University of Norway (UiT) under the project "Simulation Based Learning in Aviation."

Action research can be defined as an action-oriented approach to a prescriptive case study process, combining problem-solving with research in a way that is appropriate to the circumstances of the research to provide both academic rigor and practical relevance (McManners, 2016; Bradbury, 2015; Rowell et al., 2017). Typically, the action research model covers a spiral of cycles: planning, acting, observing, and reflecting (Altrichter et al., 2002; Dana, 2013). It is a process involving not only intellectual inquiry but also development, reflection, action, and replanning.

Action research methodology is critical in the sense that researchers not only look for ways to improve their practice but are also critical change agents of those constraints and of themselves (Altrichter et al., 2002). It is also participative, meaning that all those involved in the research process contribute equally - no one is conducting research from an external perspective but as a partner and "an owner". Considering these frameworks, a tactical plan was developed to achieve the research objectives and acquire useful knowledge from the project implementation process.

The design of action research followed stages of the process adapted from the relevant literature. Different phases of the research process are presented in Figure 1.

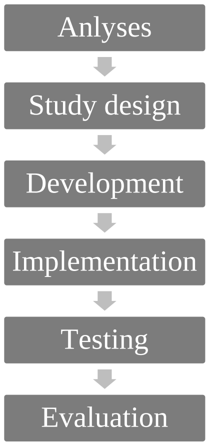

Figure 1: Phases of action research (adapted from Corrigan et al., 2015; Zon et al., 2012).

The research methodology applies to various activities during the project implementation. These activities include joint seminars and workshops, the design of SIMIO models, testing, training in simulation-based learning, and subsequent testing and evaluation.

3 Process of Research

The following explains the study phases and their outcomes.

3.1 Analysis

The analysis phase involves a systematic examination of information accumulated during the project's preparation and implementation stages. There was a clear understanding of the need to implement SBL methods in both institutions. All information gathered through curriculum development, study observations, surveys, interviews, and tests was organized systematically to support the project's implementation. Three problematic issues were identified during this phase. First, there was a need to determine how closely the developed models were linked to real industry scenarios. Second, addressing how to implement these models within the current study process and exploring the possibilities of replacing traditional teaching methods with model-based learning. Third, evaluating the sophistication level of the models to ensure their optimal use in the educational setting.

This stage also includes the research process and outcomes, considering the researcher's own actions and biases.

Based on this comprehensive analysis, an action plan was developed for the next cycle of action research. This plan aims to refine the models, enhance their integration into the study process, and ensure they are effectively aligned with industry practices.

3.2 Design

The learning module consisted of three interrelated digital courses and is called the "Aviation Operation Simulation Module." The core of the module is a specialized platform or simulation modeling software. Based on this platform, two specialized courses (each worth 9 ECTS) and an introductory course on the software program itself (6 ECTS) have been developed. The existing software program has been acquired, and the courses are designed based on it.

Using the software, simulation models were developed to imitate operations common in the aviation industry. In perspective, students were introduced to how to use such tools in their professional careers. This approach aims to provide students with practical skills and knowledge directly applicable to their future roles in the aviation sector. Through these courses, students learned to navigate and utilize the simulation software effectively, allowing them to better understand and manage aviation operations.

3.3 Development

During the project, three courses were developed, each incorporating various simulation models. The development of these courses proceeded as follows: students will learn how to digitally simulate (i.e., model) airport or airline operations. Simulation-based imitation of real activities enables students to comprehensively understand how sophisticated aviation systems function. Besides acquiring skills in computer modeling, students will also learn about aviation processes and procedures that often cannot be simulated by computer models. For instance, they will study constraints from arctic conditions, safety requirements, and international regulations applicable to aviation. Within the courses, students will design their own simulation models (based on scenarios provided by instructors) to demonstrate their skills and creativity.

Most of these courses were integrated with the existing courses at the participating institutions. However, the project's purpose was to restructure the teaching methods of these courses.

The first integrated course is titled Airport Operations (C1), and the second set of courses is Airline Operations (C2). The first set of courses was developed by the Estonian Aviation Academy (EAVA), and the second by UiT. The third course (Simulation Modeling Software, C3) was jointly developed by EAVA and UiT.

The first course (Airport Operations, EAVA) teaches students to build computer models for airport activities. It covers aspects such as airport operations fundamentals, customer service management, passenger and cargo handling, capacity building, safety, and more.

The second course (Airline Flight Operations, UiT) teaches students to build computer models for airline operations. It includes principles of operations (particularly in Arctic conditions), flight planning, managing cargo operations, and other relevant aspects.

The third course (Simulation Modeling Software, EAVA and UiT) provides students with practical skills on using the simulation software program. All course materials will be digital and freely available to students. The course content will be supported by teachers' manuals, prepared by the partners responsible for developing the course content. Additionally, manuals and workbooks for students will be developed, with those for the third course created jointly.

The software program SIMIO was used for generating and teaching simulation models. SIMIO is widely recognized and used by academic and business institutions. It is available for academic purposes (teaching) free of charge.

3.4 Implementation

The project focused on modeling begins with setting clear and achievable goals. This foundational step ensures that both educators and students have a shared understanding of the objectives and outcomes expected from the course. Tasks were shared between participating institutions, and teachers individually built models, which were later discussed jointly. Each model was analyzed and explained in detail during joint workshops.

Individual model development by the teachers allowed for a deeper understanding of the subject matter with students' needs in mind. Along with model design, the courses were rearranged and supplementary teaching materials, such as slides and teacher manuals, were developed. As the digital models are technically sophisticated, detailed explanations were added to each model.

Following the individual efforts, joint seminars were organized where participants introduced their models to their peers and partners. These seminars served as platforms for collaborative activities and deeper cooperation.

The final part of the project involved testing the models in the actual teaching process. This testing phase was crucial to evaluate the effectiveness of the models and ensure they met the educational goals. Feedback from students and instructors was collected to refine the models and teaching materials further, ensuring a robust and practical learning experience.

3.5 Testing

To ensure that students can effectively use and benefit from these models, teaching sessions are conducted. These sessions are designed to equip students with the necessary skills and techniques to utilize the models in various scenarios, making the learning process more practical and applicable.

Finally, the program includes a comprehensive evaluation of students' progress. This evaluation is essential to measure the effectiveness of the teaching methods and the students' understanding and application of the models. Regular assessments help in identifying areas of improvement and ensuring that the educational goals are being met efficiently.

To test the simulation-based learning (SBL), a course titled "Airport Operations" was conducted. The testing phase of SIMIO teaching included the integration of models specific to airport ground processes and passenger flow. The class chosen for the testing included students from the final year degree program at the Estonian Aviation Academy and Erasmus students from other parts of Europe. The teaching was conducted mostly face-to-face, with hybrid sessions as needed.

The first step of testing involved introductory teaching sessions, including discussions about the importance of simulations and basic information about the SIMIO software. The teaching continued by highlighting the successful application areas of SIMIO across many industries, including manufacturing, aerospace, defense, and industrial engineering. Considering the students' interest, extra materials were provided to cover the importance of SIMIO use in different fields.

The hands-on experience with SIMIO began in the second step of teaching. The basic Source-Server-Sink (SSS) model was built using general examples (Figure 2).

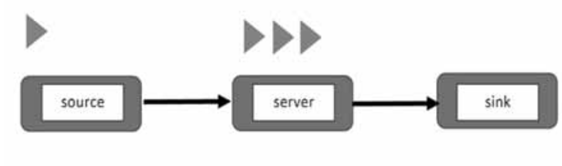

Figure 2: Principal model design.

Detailed instructions were provided for the arrival of entities, the processing properties, and the types of processing methods for each entity at the server. For advanced learning, the use of multiple server models and examples were also taught in the class.

During the practical training, students were grouped into teams of two or three people to achieve the following objectives:

1. Understand the sample problem statement by recognizing the given details of the sample model and identifying what needs to be found using Simio simulations.
2. Identify the elements and resources required to build the basic model.
3. Specify server capacity and processing properties.
4. Successfully execute the model.
5. Read and interpret the results table after executing the model.

The majority of the students showed great interest in learning the visual representation of the problem and attempting to find reasonable solutions. A significant percentage of students advanced their skills quickly, asked questions, and discussed model improvements. The feedback on the teaching and practical sessions was impressive. The teaching continued for a few weeks with introductory lectures and practical training.

As practice for students, solved modeling problems from the built-in SIMIO SimBits and examples provided by the instructor were regularly used. During practical sessions, students were encouraged to ask questions about the model-building and solution strategies and to participate in discussions. Advanced aviation models regarding optimizing ground-side processes, passenger flow in the terminal, and flight arrivals/departures were also presented to spark students' interest.

To conclude, SIMIO modeling is a valuable tool for studying and analyzing airport operations at any stage. From the airport management perspective, whether landside or airside, terminal operators could benefit from running simulations beforehand by inputting flight schedules and passenger quantity details into the model.

3.6 Evaluation

The attempt to teach SIMIO, a modern simulation tool, at the Estonian Aviation Academy was successful, driven by the strong interest of the students. The instructor's step-by-step instructions and detailed discussions about problems and their potential solutions significantly enriched the students' experience with simulation modeling, guiding them effectively through the learning process. Practical training sessions were identified as the most successful method for teaching SIMIO, allowing students to apply theoretical knowledge in practical scenarios. This hands-on approach not only facilitated better understanding but also enhanced their problem-solving skills.

Given the success of practical training, future SIMIO courses will prioritize practical sessions and one-to-one discussions. This approach will ensure that students receive personalized guidance and have ample opportunities to engage deeply with the material. At the end of the course, students' skills were assessed through group or individual projects and assignments. These assessments included practical demonstrations of the solved problems, accompanied by detailed reports analyzing the problems. This comprehensive evaluation process ensured that students could effectively demonstrate their understanding and application of SIMIO modeling, highlighting the effectiveness of the practical, discussion-based teaching approach.

4 Results and Conclusions

The integration of SIMIO software into aviation management education at the Estonian Aviation Academy has demonstrated significant benefits. It ensured students gained practical skills and a deeper understanding of complex aviation operations, effectively bridging the gap between theoretical knowledge and real-world application. The SIMIO modeling environment allowed students to visualize and interact with sophisticated aviation scenarios, making the learning process more engaging and relevant. Students responded positively, appreciating the hands-on experience and the relevance of the simulations to real-world situations.

The practical applications of SIMIO enabled students to see the direct consequences of their actions within simulated environments, fostering a deep understanding of aviation management principles and practices. This practical approach also helped students develop a wide range of essential skills, including technical, functional, problem-solving, decision-making, and communication competencies.

This experience suggests that other educational institutions could benefit from adopting similar SBL models. Future research could explore the long-term impacts of such educational approaches on students' career readiness in the aviation industry. Additionally, expanding the use of SBL to cover more aspects of aviation management and incorporating feedback from industry professionals could further enhance the curriculum.

In conclusion, the use of SIMIO software for simulation-based learning in aviation management represents a positive experience in Estonian Aviation Academy's educational practice. SIMIO provides a valuable model that other institutions can adapt to enhance their educational offerings and prepare students for the challenges of modern aviation management.

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