From lab to real life: A case study in the deployment of advanced driving simulator-based training systems

Matthew R. E. Romoser[1] & Pierro Hirsch[2]
[1] University of Massachusetts Amherst, Arbella Human Performance Laboratory, Amherst, Massachusetts
[2] Virage Simulation Inc., Montréal, Québec, Canada

Simulator-based training platforms have the potential for facilitating learning in a safe and controlled environment. Trainers can provide students with simulated scenarios representing a large number of challenging situations to help the student gauge their own performance, learn from their mistakes, and gain experience with complex skills through repeated practice. Often, novel ideas for new simulator-based training systems are initially developed and tested in a laboratory setting. However, understanding how best to implement simulators for use in practice is not a trivial undertaking. A concurrent engineering process that involves the researchers, practitioners, engineers, trainers and other end users is required. Designers must understand the requirements and the barriers to implementation, and the only way to accomplish this is to understand the end users and include them in design process. The current paper discusses a novel model describing the implementation cycle for the development and deployment of advanced driving simulator-based training systems and provides a real-world case example of one such successful deployment.

INTRODUCTION

Over the past several decades, simulators have become popular in many fields as a means of teaching complex or advanced skills. Using a simulator, skills can be practiced in an environment that is safe, allowing the student to learn from errors without negative real-life consequences. The student can quickly gain experience with repeated trials in scenarios that can be manipulated by the trainer to simulate various hazardous or complicated situations. This allows the student to quickly learn how to master higher order skills such as scanning their environment more effectively, handling higher workloads, identifying critical information and making better decisions quickly.

Based on the long-established and successful application of simulator-based training in the aviation industry, researchers have investigated the application of simulator-based training for drivers (Blickensderfer et al., 2005; Pradhan, Pollatsek, Knodler, & Fisher, 2009; Romoser & Fisher, 2009; Pollatsek, Romoser & Fisher, 2012). Many administrators of truck training centers have considered and some have tried using truck simulators in their operations. However, the majority of truck driver training centers still operate without simulators. One potential reason for this is that the technology has not been implemented correctly.

The successful transition from the academic or simulator company research laboratory to real life is rarely as easy as shipping the simulator from the lab and to the practitioner. Often the technology that was developed and tested in the lab is not immediately suitable for use or the end users are insufficiently trained to operate the simulator or understand the data it collects Before simulation technology can be translated for use in practice, careful consideration must be given to contextual factors such as the goals of the organization, the expectations and expertise of the users, the operating budget, the environment the simulators will be used in, and how performance data will be utilized.

As with any new technology, instructional simulators have an implementation cycle that must be understood and

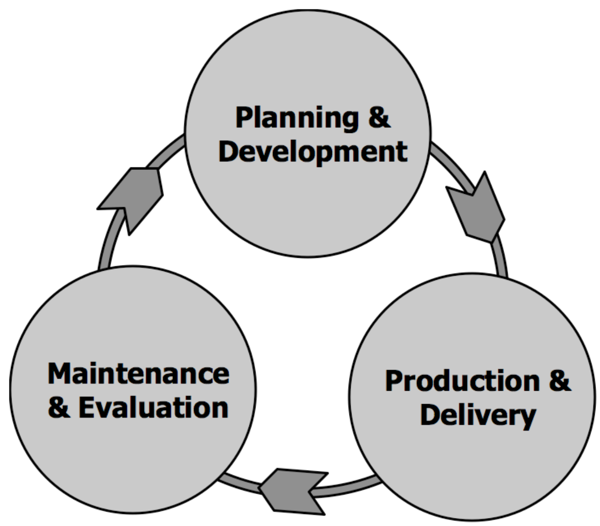

Figure 1. Instructional technology implementation cycle (Bacsich, et al., 1999).

respected. To help visualize this cycle, Bacsich, et al. (1999) developed a three-phase working model for instructional technology development and implementation (Figure 1).

This three-cycle model was originally designed to help the people involved in making economics decisions better understand the costs of developing instructional technology. However, we believe this model also provides an excellent starting point from which to begin discussing the design and human-factor challenges associated with how to translate simulator-based instruction that is developed and tested in the laboratory to real world practice. In the present paper, we expand upon the model of Bacsich et al., and illustrate with references to a real-world case study how this model has been successfully applied to the translation of simulator-based instruction from the laboratory to a fully operational truck driver training center.

 DOI 10.1177/1071181312561525

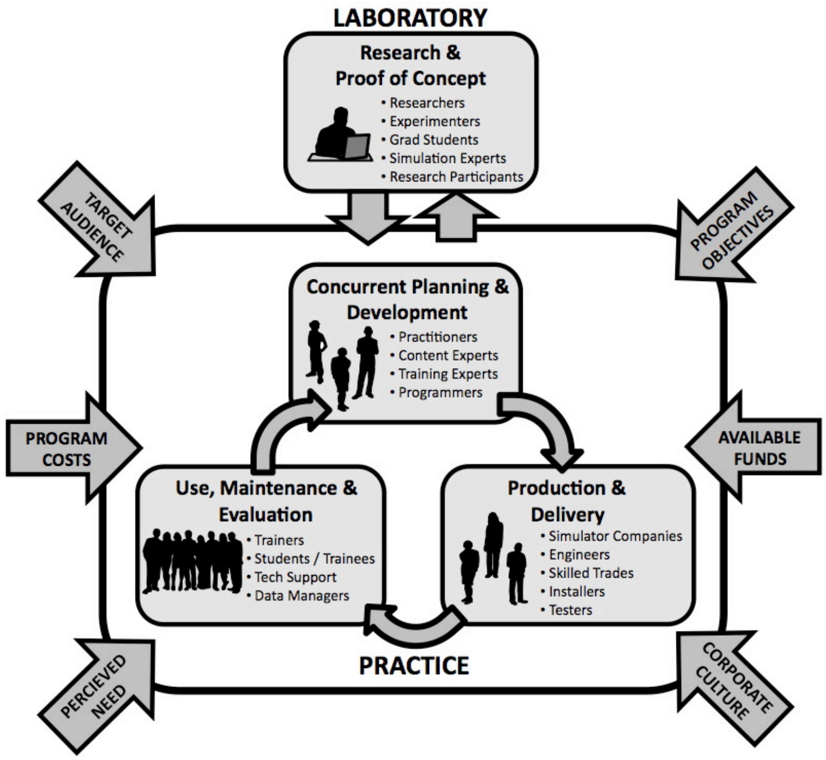

Figure 2. A translational engineering model for the development and implementation cycle of simulator-based training systems. (based upon insights from Bacsich, et al. (1999).

THE SIMULATOR-BASED INSTRUCTION IMPLEMENTATION CYCLE

At some point, most ideas for a novel simulator-based training were first developed and tested in a laboratory setting. The research team working on the system is often comprised of some combination of researchers, experimenters, graduate students, and simulation experts or programmers. The researchers have specialized knowledge in the field of simulation and training and are the ones who seek funding for the program and set the groundwork and requirements for a system necessary to test their hypotheses. A team of simulation experts (may be the same people as the researchers themselves, may not), programmers, and graduate students then are employed to build the simulator-based training system that will be tested. Special equipment is sometimes required in the simulator to collect data to help test certain hypotheses. This equipment might include eye trackers, physiological measuring equipment, specialized sensors, and cameras, the data from which might require conversion from an analog to digital format such that is can be recorded alongside data normally collected by the simulator's computers. Once the simulator-based instruction system has proven itself to be effective in training students, then focus can shift to designing a system for use in practice.

The development of an effective simulator-based training system for use in practice can be understood as an exercise in concurrent engineering. As opposed to the more antiquated "toss it over the wall" approach to design, concurrent engineering is generally accepted to be a more efficient and effective method of designing a product or system. By definition, concurrent engineering describes a design process wherein there is a collaborative effort between engineers, production, customers, and management to define the specifications and design aspects of a system. By doing so, individuals in all aspects of the system's implementation cycle have input on the design of the system, thereby reducing the likelihood of costly oversights, errors and omissions in the final product. The needs of the trainer and student are certainly important, but for the training system to maximize its potential, a designer must also consider the needs of all the individuals in the cycle that will be involved or interact with the technology.

Once the specifications for the system have been finalized, the focus shifts to production and delivery to make good on those designs. The production and delivery team will have been interfacing closely with the planning and development team. A system that holds true to the system that was initially studied in the lab while still meeting the needs and limitations of real-life application in the field must be designed. The needs of the individuals involved in this phase include the need for careful documentation of the design and concise specifications for any software development. Those individuals with the trade skills who will be doing the physical construction of the simulator should have accurate documentation and bills of material from which to work and access to the appropriate members of the design team should questions arise. For the purposes of use, maintenance and evaluation, training experts and practitioners should interface directly with the engineers and programmers who will implement the simulator system. The completed system should have built into it clear and concise instructions for the student. Before a simulation begins, the student should know what it is they are about to learn, how they are going to learn it and why it is important. A means for data collection should be put in place to provide the system and trainer a means of assessing student performance and to allow engineers and researchers to assess the long-term effectiveness of the deployed training system.

The model described in Figure 2 expands on the model in Figure 1 in two principal ways. One, Planning and Development in Figure 1 is divided into two categories connected by bi-directional arrows, Research and Proof of Concept and Concurrent Planning and Development. The bi-directional arrows indicate that research may be beneficial or necessary throughout the lifetime of the implementation of the new technology. The division also recognizes at the outset that the questions and agendas of researchers and practitioners may differ. For example, researchers may want to focus on training goals for simulator scenarios that practitioners feel are already adequately addressed in vehicle.

Some of the reasons for these differences may be found in the second principal way that the model in Figure 2 is different from that in Figure 1, the addition of contextual factors labeled within the inward pointing arrows that encircle the implementation cycle. These arrows represent the various influences that potentially affect the successful implementation of new technologies.

The model presented in Figure 2 represents an interactive and iterative process with four distinct phases: Phase 1, *research and development*; Phase 2, *concurrent planning* and *development*; Phase 3, *production and delivery*, and; Phase 4, *use, maintenance and evaluation*.

TRUCK SIMULATOR IMPLEMENTATION CASE STUDY

This case involves three organizations, a driving simulation company, a truck driver training center, and a research university. Virage Simulation is a Montreal-based simulator manufacturer founded by aviation simulation engineers that employs a full time road safety researcher with extensive driver training experience. The Centre de Formation en Transport de Charlesbourg (CFTC) is a multi-site professional truck driver training school in Quebec, whose mission statement includes support for t for research and innovation. The CFTC employs over 100 professional teachers for their 16-week long courses and they graduate 1,000 students annually. The HEC Montreal provides research expertise and university graduate students and channels funding to research projects including those that concern road safety.

The case study outlined below describes the activities in each of these phases throughout six iterations of the implementation cycle from 2008 to the present. The truck simulator underwent six complete implementation cycles (versions) and, with the exception of research and development which happened only in cycles one, three and five, examples of each phase of the concurrent engineering implementation cycle can be cited. Below we discuss each of these cycles and what occurred within each phase of the cycle. Note how, with each subsequent implementation cycle, feedback from users and team members was subsequently implemented in the next cycle using the same multi-phase implementation approach.

First Implementation Cycle – 2008 to 2009

In 2008, Virage Simulation, developed a car simulator and training program for novice drivers that was accepted by the Quebec government for pilot testing in Quebec driving schools. Shortly afterwards, Virage Simulation was approached by the CFTC, to provide them with a VS600M truck simulator (see Figure 3). The CFTC collaborated with Virage Simulation by giving the simulator engineers access to their fleet of trucks to validate the physical models they were simulating and by allowing the training scenario developer to consult with the truck driver trainers.

Cycle 1: Phase 1 - Research & Proof of Concept. Virage Simulation earned approval from the Quebec government to conduct a long-term, transfer-of-training (ToT) study for car simulator-based novice driver training within Quebec driving schools. Work began on the implementation of driving scenarios and testing them in a laboratory environment.

Cycle 1: Phase 2 - Concurrent Planning & Development. Concurrent engineering is generally accepted to be an efficient and effective method for designing a product or system because it encourages or requires collaboration between engineers, production, customers, and management in defining the specifications and design aspects of a system. During this phase, select teachers from the CFTC tested the simulator and suggested improvements to the training scenarios developed by the programmers and engineers at Virage Simulation. Virage Simulation independently conducted multiple tests with local truck drivers and trainers to validate the feel and function of the physical truck models they developed for the simulator.

Contextual factors also need to be carefully considered. For example, budget limitations may arise due to lack of available funds or due to a corporate culture that does not prioritize investments in training technology. Lack of available funds may force trade-offs that could undermine the ultimate success of the project. In this case study, the administration of the CFTC demonstrated a strong commitment to the project by allocating a multi-year annual budget to acquire more training software.

Cycle 1: Phase 3 - Production & Delivery. After the specifications for the system are finalized, the focus shifts to production and delivery. The production and delivery team worked closely with the researchers and designers and the necessary modifications made to the design to address any issues with manufacturing and deployment of the system. The first VS600M truck simulators were produced and delivered to CFTC. In addition, Virage Simulation delivered extensive training to CFTC technicians and selected trainers on how to operate, maintain and trouble shoot the system. Special training was given to trainers on the differences between teaching on the simulator and in the truck.

Cycle 1: Phase 4 - Use, Maintenance & Evaluation. Not only are the needs of the instructor and student important. The needs of those individuals who are tasked with maintaining and evaluating the long-term effectiveness of the system must also be taken into consideration. Instructors require a means of effectively gathering data and information to provide students with meaningful feedback. Similarly, a plan on how to record data on training outcomes and system performance needs to be developed to facilitate the job of engineers and researchers whose job it is to determine if the system met the original objectives and design the next iteration.

As teaching practices may vary widely, the simulator developer needs to create a structured approach to training and feedback that optimizes the strengths of simulation, e.g. standardized routes, traffic, events and objective feedback. Training the trainer to understand and respect these strengths is critical to successful implementation. In our case study, an effort was made to reduce the number of potential misunderstandings by inviting trainers and have input into the system's initial design and production, phases 2 and 3.

During this first iteration of the implementation cycle, CFTC management encouraged, but did not require, their trainers to adopt the VS600M within their training schedules. Management discovered that the majority of the CFTC trainers resisted using the simulator. An investigation concluded that improvement in the learning software could increase the adoption rate. Management and trainers identified gear-shifting skills as the target for the first scheduled software purchase.

Second Implementation Cycle – 2010 to Early 2011

Cycle 2: Phase 2 - Concurrent Planning & Development. Training experts and programmers from Virage Simulation and the CFTC collaborate to conceive, plan and develop the Golden shifter (GSP). The GSP is a competency-based, self-paced learning program consisting of four interlinked modules. Each module is designed to allow learners to complete progressively more complex and difficult aspects of shifting gears at their own pace and without teacher supervision. Learners must accumulate a predetermined score to obtain a certificate and progress to the next step.

Cycle 2: Phase 3 - Production & Delivery. Engineers at Virage Simulation develop and test the GSP system with ongoing feedback from end users. The GSP is produced and installed in the VS600M truck simulators at the CFTC.

Cycle 2: Phase 4 - Use, Maintenance & Evaluation. Increasing numbers of CFTC trainers report that during the first in-truck lessons, learners with GSP training are markedly better than learners without GSP training. The rate if voluntary adoption of simulator-based training by CFTC trainers improved.

Third Implementation Cycle – Mid 2011

Cycle 3: Phase 1 - Research & Proof of Concept. The researchers at Virage Simulation propose a ToT study to confirm the anecdotal evidence of the success of the GSP. Work begins to develop training scenarios and modules for a controlled laboratory study.

Cycle 3: Phase 2 - Concurrent Planning & Development. Experts from Virage Simulation, the CFTC and the HEC Montreal collaborate to plan the Transfer of Training Study of the GSP.

Cycle 3: Phase 3 - Production & Delivery. The ToT study is conducted with a sample of CFTC students from different training sites.

Cycle 3: Phase 4 - Use, Maintenance & Evaluation. The ToT data is collected and analyzed. Findings support the hypothesis that the GSP is effective. The results from learners who achieved their Golden Shifter certificate showed a Training Efficiency Ratio of 2.4 to 1, meaning that one hour of self-paced learning on the simulator had the same training effect as 2.4 hours in a truck with an instructor. However logistical problems and lack of control of confounding variables weakened the conclusion. Improvements are proposed for the GSP, i.e. instructional video clips to be viewed in the simulator. A follow-up ToT study was planned.

Fourth Implementation Cycle – Late 2011

Cycle 4: Phase 2 - Concurrent Planning & Development. Improvements to GSP are developed by Virage Simulation and CFTC experts. Additional VS600M truck simulators are ordered to increase throughput.

Cycle 4: Phase 3 - Production & Delivery. VS600M truck simulators are delivered. The GSP improvements are loaded on all the VS600M truck simulators at the CFTC. A larger facility at the CFTC is renovated to house the new VS600M truck simulators.

Cycle 4: Phase 4 - Use, Maintenance & Evaluation. CFTC trainers are given "booster" demonstrations of the efficiency of the VS600M and training programs. Completion of the GSP certificate became mandatory prior to 1st in-truck lesson.

Fifth Implementation Cycle – Late 2011

Cycle 5: Phase 1 - Research & Proof of Concept. A second ToT study, with better control over some but not all of the known confounders, was planned by researchers from Virage Simulation, the CFTC, and the HEC Montreal. The HEC Montreal provided expertise and a channel for some of the funding needed to carry out evaluations of the transfer of training effectiveness.

Cycle 5: Phase 2 - Concurrent Planning & Development. Experts from the CFTC and Virage Simulation conceive, plan and develop the Golden Mirror Program (GMP) to learn backing skills and the Golden Steering Program (GStP) to learn turning corners, both self-paced programs consisting of multiple linked modules that allow learners to achieve competence at their own pace and without teacher supervision. Additional VS600M simulators are ordered, including two mobile units for use in the satellite locations of the CFTC.

Cycle 5: Phase 3 - Production & Delivery. New VS600M simulators are delivered. The GMP and GStP programs are installed in all the VS600M truck simulators at the CFTC.

Cycle 5: Phase 4 - Use, Maintenance & Evaluation. Due to scheduling constraints within the CFTC curriculum, use of the new training programs (GMP and GStP) is limited. Findings from the second ToT study support the hypothesis that the GSP is effective but the influence of one confounding variable remains problematic.

Sixth Implementation Cycle – 2012 to present

Cycle 6: Phase 1 - Research & Proof of Concept. A third ToT study was planned to control for the effects of the remaining confounder within the GSP study and also to evaluate the effectiveness of the GMP and GStP.

Cycle 6: Phase 2 - Research & Proof of Concept. The third ToT study is currently being carried out to evaluate the effectiveness of truck simulator-based, self-paced training for shifting, backing and steering (the GSP, GMP and GStP).

Figure 3. The VS600M is built with real truck components on a three degree of freedom motion / vibration platform and surround sound. Learners have a 180-degree forward field of view plus rear view mirrors and the manual shifter provides realistic force feedback and vibrations.

CONCLUSION

In 2007, the CFTC had one or two truck simulators that were rarely used by their teachers or students. Since 2008, the CFTC have acquired nine additional simulators, all of them VS600M models and three self-paced training programs. The adoption rate by the teaching staff is very high and every student must now acquire the Golden Shifter Certificate before starting their in-truck training. Some of these truck simulators are mobile units that travel to the CFTC's satellite locations.

The case study presented in this paper demonstrates that the successful implementation of a novel learning technology, truck simulators, follows the steps and is subject to the influences outlined in the translational engineering model. Arguably the single most important influences are the available funds and the corporate culture. In this case study, the CFTC management cooperated fully by allocating the funds to purchase a sufficient number of VS600M truck simulators to meet their throughput needs, including those of satellite training centers where mobile simulator units are required, as well as dedicated training programs on annual basis. The corporate culture of the CFTC management was also aligned with the success of the project by actively promoting the benefits of simulator-based training at regular pedagogical assemblies, thereby nurturing the adoption of the new technology by CFTC teachers who initially resisted the change. The CFTC also cooperated fully with researchers from Virage Simulation and HEC Montreal in the transfer of training (ToT) evaluations and immediately implemented the recommendations of the evaluation studies (see Hirsch et al., 2011).

A second necessary element to the successful implementation of a novel learning technology is the involvement and continued support of the technology provider, in this case Virage Simulation. A third important element is the research contribution of the HEC Montreal that provided the expertise, research students and a channel for funding needed to carry out evaluations.

One note of caution – the relatively fast implementation and apparent effectiveness of a learning technology may exceed the adaptive capabilities of an existing training system. Currently, the CFTC trainers have not yet fully integrated the new training software for backing and turning into their curriculum.

In summary, new educational technologies like simulator-based training have great potential for facilitating and improving the learning of driving skills. When the implementation of these technologies is understood and treated as a continuous process whereby the end user, the technology provider and potentially a third-party researcher collaborate and undertake regular evaluations of training efficiency, these new technologies have the potential to reach their maximum value.

REFERENCES

Bacsich, P., Ash, C., Boniwell, K., Kaplan, L., Mardell, J. & Caven-Atack, A. (1999). *The Costs of Networked Learning*, Sheffield: Sheffield Hallam University.

Blickensderfer, B., Liu, S. and Henrandez, A. (2005). *Simulation-Based Training: Applying lessons learned in aviation to surface transportation modes*, Embry Riddle Aeronautical University.

Hirsch, P., Pignatelli, S. and Bellavance, F. (2011). *An Evaluation of Truck Simulator-Based Training on the Acquisition of Gear-Shifting Skills*. 21st Canadian Multidisciplinary Road Safety Conference. (2011) Halifax, Nova Scotia. May 8-11, 2011

Pollatsek, A., Romoser, M. R. E., & Fisher, D. L. (2012). Identifying and remediating failures of selective attention in older drivers. *Current Directions in Psychological Science, 21,* 3-7.

Pradhan, A. K., Pollatsek, A., Knodler, M., & Fisher, D. L., (2009). Can younger drivers be trained to scan for information that will reduce their risk in roadway traffic scenarios that are hard to identify as hazardous? *Ergonomics, 52,* 657-673.

Romoser, M. R. E. & Fisher, D. L. (2009). The effect of active versus passive training strategies on improving older drivers' scanning for hazards while negotiating intersections. *Human Factors, 51,* 652-668.