# From Classroom to Field: Topological and Tactical Terrain Analysis Inside a Learning Environment

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## ABSTRACT

One of the biggest concerns in planning a military operation is how to explore the terrain, avoid collateral damage and accomplish the mission. During that process, military planners study the topographic and tactical aspects, gathering detailed information to better advise superiors in their decisions. Learning how to prepare for that terrain study takes time and practice, and inside the classroom is difficult. Because of that, sometimes students are taken into regions in a Field Exercise (FE) to understand how to conduct this kind of activity. Even participating in those FE, it is quite difficult for the instructor to explain to students the subject given the abstraction needed to visualize, for example, the coordination measures for an operation in the area, the company moving to an objective, and so on. Another problem happens when the instructor points to a place and makes observations about that area, while the student accidentally looks at the wrong place and starts learning the content in the wrong way. Trying to solve similar problems, Wenqiong Du et al. (Du et al., 2022) developed a Mixed Reality-based platform addressing nontechnical skills personnel for Battlefield First Aid (BFA) training with satisfactory effectiveness. In this work, the interaction between the real and the virtual world was fulfilled by using the HTC VIVE VR Headset. In this context, we propose "Simulador Virtual para Estudo Topotático do Terreno (SVETT)," a simulator that uses resources usually found in classroom involving 3 interfaces (Virtual Reality, projection, or constructive) that can help instructors to ease teaching the abstract subjects of a terrain study and standardize the knowledge learned from students. The Brazilian Marines Simulation Center developed SVETT and evaluated it with 54 students. The results suggest that using SVETT first, students found participating in the field exercise easier because of their previous contact with the region.

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## INTRODUCTION

To conduct military operations, planners must make a comprehensive analysis of the operating environment, its components, actors and their relationships (NATO, 2019). Those factors will influence the operation planning process, which is done by highly trained personnel, capable of interpreting all topographic and tactic data, which normally involve aspects related to relief, enemy, vegetation and climate, known together as operational aspects of the terrain (NAVAIS, 2020).

Teaching and training military personnel about this type of activity is sometimes difficult within a closed classroom. Therefore, students are usually taken to different regions in Field Exercises (FE), so that they can have better contact with the terrain and understand what should be considered for their study. Even participating in those FE, it is quite difficult for the instructor to explain to students the subject given the abstraction needed to visualize, for example, the coordination measures for an operation in the area, the best place to plan a position for a certain military facility, a company moving to an objective. Another problem happens when the instructor points to an area and makes observations about that place, while the student accidentally looks at a wrong place and starts learning the content in the wrong way.

Using simulation to solve similar problems, Wenqiong Du et al. (Du et al., 2022) developed a Mixed Reality-based platform addressing nontechnical skills personnel for Battlefield First Aid (BFA) training with satisfactory effectiveness. In this work, the interaction between the real and the virtual world was fulfilled by using the HTC VIVE VR Headset. Also in another work, Govan and Guest (Govan & Guest, 2021) created a synthetic environment using Virtual Reality (VR) to conduct training for team-based water diving procedures. The training was conducted safely and efficiently in representative visual conditions, also allowing for the use of scarce equipment, representing a significant improvement over the current classroom-based training.

Based on the worldwide trend where the development of different categories of simulators (Arbia & Ouersighni, 2012) enables higher quality training and the consequent preparation of the Troop, always considering the fact that a real exercise should never be replaced, a great opportunity arises from the following questions: Is it possible that the concatenation of the concept of a Learning Environment (LE) and resources usually seen in classroom can offer educational capabilities to better understand terrain analysis even before the presence in field? What if the students have already arrived at the training site having a previous contact with the region, that is, having already solved the most basic doubts inside a classroom and leaving only the most complex or peculiar activities to the field?
By immersion in a precisely reproduced Synthetic Training Area, the first contact with the terrain could be made already in classroom. With the availability of resources that the real terrain does not allow, such as drawing on the terrain for an explanation, the results of this interaction would bring great benefits from an educational point of view, creating conditions for better study during training in FE itself. With that, learning could increase significantly.

In this sense, Brazilian Marines Simulation Center developed, for Brazilian Marines purpose only, a simulator called SVETT (In English: Topographical and Tactical Terrain Study Simulator). This simulator has the purpose of facilitating the transmission of knowledge by the instructor, as well as unifying the students' understanding using its tools. The objective of this study is to evaluate whether the platform resources can offer both education and capabilities for real situations to better understand terrain analysis in the Basic Terrain Study. We developed SVETT and evaluated it with 54 students. The results suggest that, using SVETT first, students will find it better when participating in the Field Exercise because of their first contact with the region in classroom.

The next section presents details of a standard terrain study. In the third section, we describe the concepts of the proposed simulator. The fourth section details the methodology for the evaluation process of the proposed solution. The fifth section presents the results found and the discussion of our study. In the last section, we present final conclusions and potential future work.

## THE TERRAIN STUDY

To maintain a military Planning Cell's flexibility and operational capacity for conducting Military Operations, it is important that everyone understands their tasks, when it becomes essential to create quality operational documents (NAVAIS, 2022), capable of clarifying and exploring the operational aspects of the terrain (NAVAIS, 2020).

Teaching military personnel how to study a region for conducting military operations is sometimes difficult within a closed classroom. One way to solve this problem is to observe an image and compare it with a topographic map, which, in most cases, is very difficult because it does not convey an adequate spatial notion. Therefore, in Brazil, students are usually taken to different regions, so that they can have better contact with the terrain and understand what should be considered for their study.

In these opportunities, students and instructors occupy positions that allow the best observation of the terrain and in good conditions, which are, generally, at the top of the highest elevations. To start the study, we need to understand the process where we seek to observe the characteristics of the terrain that can decisively influence the actions in a certain location, known as Basic Terrain Study (BTS)

BTS is the identification on a Military Map (MM) of the various reference points with importance to the operation on terrain. This study is limited to four kilometers because of the difficulty of observing beyond this distance without proper equipment. In the BTS, the Station Point is identified, which is the current position of the students, as well as the important terrain references for the operation, like elevations, rivers, roads and so on, which can significantly influence the operation planning and execution. After that, the tactical study of terrain begins.

## PROPOSED SOLUTION CONCEPT

SVETT is a simulator used to study the topographic and tactical aspects of the terrain, known as operational aspects. This section details how we ended up with the concept of SVETT and how it works to enable the interaction between instructors and students.

Analyzing the current study situation, when the class is at the field exercises, we found that instructors sometimes have difficulty passing some concepts to students because of the need to imagine the Military Units or measures of coordination in the real terrain. With that abstraction in mind, the understanding of the subject may become distorted. Situations like these generate consequences such as various conceptual errors, misunderstanding in choosing suitable places for the development of military maneuvers, difficulties in solving doubts after returning to the Units, and absence of a similar place for discussions on the subject.

This terrain analysis at the FE facilitates understanding as we observe the main characteristics of the region and its conformation with a higher detail level. Looking forward to a solution about our problem abstraction, trying to concatenate the concept of a Learning Environment (LE) and resources usually seen in classroom, we found some previous studies. One aspect we considered was that the technology used to find a solution must behave in a way that suits the way students learn (Thijssen & Bosma, 2022).

In our research, we found that the cognitive ergonomics of Augmented Reality and Virtual Reality in a complex decision-making task based on real activities involving Naval Operations found importance as a training tool for the military (Stedmon & Stone, 2001). Also, advances in immersive technologies together with experience, learning theory and student interaction can provide all the tools necessary to take full advantage of immersive learning environments (Taylor & Clayton, 2021).

According to Milgram and Kishino (Milgram & Kishino, 1994), varying levels of immersive environments can be described along a virtuality continuum, where Virtual Reality (VR) is a fully virtual environment, Augmented Reality

(AR) is an environment in which the real environment is enhanced with virtual objects, and Mixed Reality (MR) describes the range between real and virtual environments in which the user interacts simultaneously with both. This continuum helps to explain not only definitions of individual immersive environments, but also illustrates the spectrum that exists from a fully real to fully virtual environment.

Michael Kozhevnikov and Maria Kozhevnikov (Kozhevnikov & Kozhevnikov, 2022) examined the effect of different viewing environments on the performance of a spatial perspective-taking task. For that experiment, 24 participants were administered a computerized perspective-taking task presented in four different views: computer desktop, three-dimensional large projector screen, three-dimensional large projection screen with tracking and fully immersive virtual environment using a Head-Mounted Display. As they expected, their findings indicate that all four showed a similar pattern of responses to real-world perspective-taking tasks.

With the technologies currently available, it would be possible to create a region similar to the place to be studied through the creation of a Synthetic Training Area (STA) and, with the addition of interaction capacity between the instructor and the student, it would be possible to provide instruction in order to increase the knowledge acquired by students even before going to the field, or afterwards if there are outstanding doubts.

Based on the results of these studies, we found that, in general terms, they complement each other and provide important concepts for creating a pleasant experience. Therefore, our tool implemented facilities based on those concepts with the aim of enabling improvements in transmission of this kind of knowledge seeking to remedy failures in the process that may occur because of misunderstandings arising from the instructor's difficulty in making himself understood.

## "SIMULADOR VIRTUAL PARA ESTUDO TOPOTÁTICO DO TERRENO" (SVETT)

To ease instructors' teaching conditions and standardize students' knowledge, SVETT was developed exploring resources usually seen in classroom, like a pen, but inserting those resources at any region created by the instructor or modeled from the real world. All students and instructors are immersed in that area and interact with each other within three interfaces developed with the aim to increase accessibility to the study and to explore terrain aspects elaborately. This section explains more about the simulator.

SVETT was developed at Brazilian Marines Simulation Center, located at Admiral Sylvio de Camargo Instruction Center. We used Unity (*Unity*, 2023) as development engine, with 3D assets and graphic objects created by using Blender (*Blender*, 2023). Also, the terrain was obtained using the asset Real World Terrain (*Real World Terrain*, 2023) and the communications layer was made possible by using Mirror (*Mirror*, 2023) and PostgreSQL (*PostgreSQL*, 2023). For the purposes of development and experiment, we used one desktop with a RTX3070Ti connected to three TV 82", one tablet Galaxy Tab A8 (*Samsung Galaxy Tab A8*, 2023) and two OCULUS QUEST 2 (*OCULUS QUEST 2*, 2023) Head Mounted Display (HMD). Those devices were connected to each other through a router (*HUAWEI WiFi AX3*, 2023), but there were no tests focusing on connections quantity because of budget limitations. All this equipment was used to iterate between a total of three interfaces, detailed in the next paragraphs.

As the aim of the simulator is to help in the study of the topographic and tactical aspects of any region, the scene for the study can be created according to the instructors needs just by using the Unity engine terrain creator or, if the focus of the study is in a real area, any Unity asset developed for that purpose can be used. Objects in the scene (trees, houses, facilities, and so on) are all static and cannot be moved. Only the objects inserted by the interfaces can be moved or edited by each other. Other possibilities include: drawing on a whiteboard, drawing in the study terrain to help mark important measures like the limit between platoons or even highlighting important points like rivers, inserting static objects like military facilities, inserting animations like a convoy moving from a point to another, marking places with a spot and naming them, viewing Military Map grids, pointing to a place and calling other users to look at that place, and showing a compass to help with orientation. On this version of SVETT, we will not change the time of the day and there will be no climate change conditions which could change visibility.

The interaction in the scene created happens through any of the three interfaces developed, which both instructor and student can use as their own demand. All interfaces can observe and interact with each other in the Virtual Environment and differ by the resources available, the view mode and the hardware. Also, all of them observe and interact at the same study area, which can be created just for the study or even modeled from the real world. The chosen area usually observes the places that will be used in the FE, because of their potential for learning and exploring the subjects covered in the classroom. The application was also developed with a focus on use during periods between the theoretical and practical instructions and after the FE if needed.

At the top-left of Figure 1, we can look at the "constructive interface". This first one is possible to be used with a tablet or a laptop, both connected wirelessly to the router. We can choose to observe the study area as a satellite image, like a photograph, or as a Military Map. In both cases, this observation is made from the top view and with an orthographic camera pointed down. Also, we can observe each other's interfaces position and direction as a unique symbology standard. This interface is capable of drawing in the terrain, inserting grids like the Military Maps on the terrain, marking areas and naming them, calling the attention of the other interfaces to a specific place and inserting objects that are observed by all the other interfaces. Also, it can teleport the other connected interfaces to a specific place, and we can move from one position to another by moving the camera with the mouse or finger. The advantage of this interface is that we can observe the study from the top and we can write all the measures and insert objects like planning on a Military Map, and those measures and objects will be seen on the other interfaces.

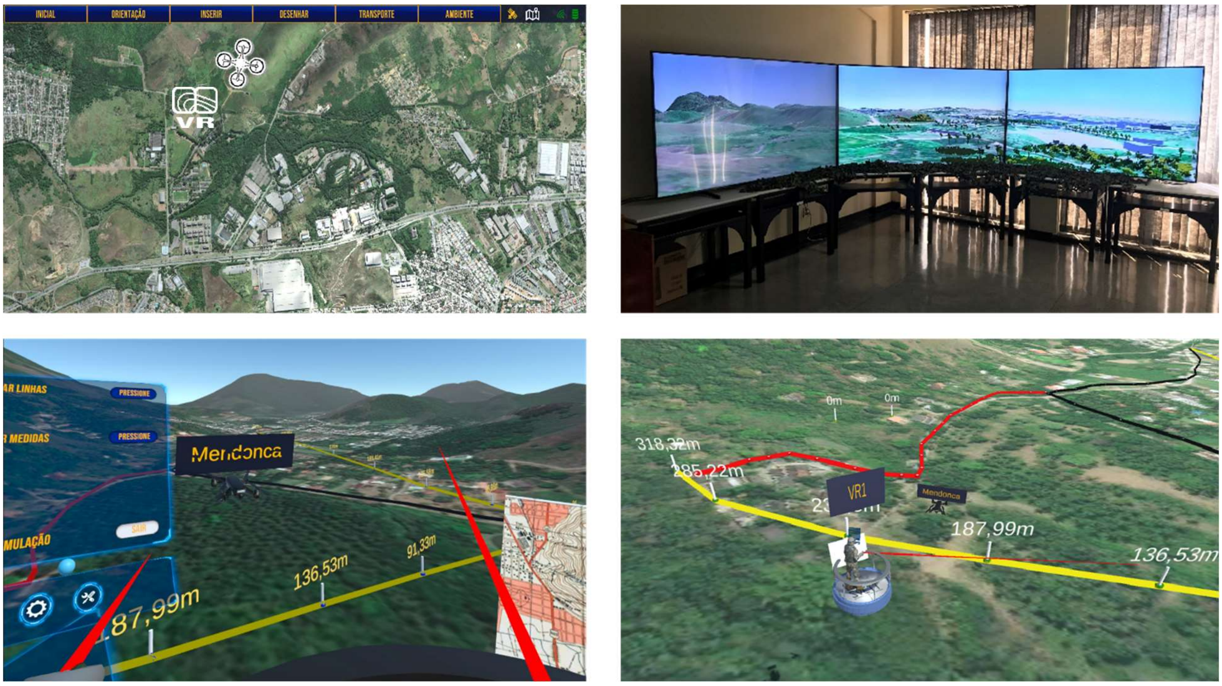


**Figure 1. On the Top-Left, the Tablet Using the "Constructive Interface", on the Top-Right, the Three TVs With the "Projector Interface", at the Bottom Left, the "Virtual Reality Interface" View Observing the "Projector Interface", Which Is a Drone At the Terrain and, At the Bottom Right, the "Projector Interface" Observing "Virtual Reality Interface" Avatar and Another Drone.**

The second interface is called "projector interface." It uses a desktop connected to a TV or even a projector and can connect to eight screens simultaneously. This interface is only capable of observing the other interfaces and changing its position by flying to the new place. We can observe it in Figure 1, on the top-right and bottom-right side. The main advantage of this interface is that one can, while giving the instruction to the students, observe the students' faces to see their expressions and detect if there are any problems in the learning process. Other advantages include the capacity to allow more students to attend the instruction and observe the annotations made by the other interfaces.

The "virtual reality interface" is the last one and uses a wireless HMD to get immersed at the study area. This interface interacts with the others on the terrain with an avatar using a military uniform. The user will be deployed above a platform that can move to any place in the area just by using the controller. This interface can draw on the terrain, insert objects and insert grids like the Military Maps that are observed by the other connected interfaces. The main advantage of this interface is the possibility to apply a more detailed study due to its immersion and the possibility to see all objects and annotations at any point of the terrain as if you were in a field exercise and, with that, have a better notion of the planning. A view of the "virtual reality interface" is shown in Figure 1, at the bottom-left side.

## METHODOLOGY

This chapter aims to explain the set of tests conducted to evaluate the tool for students, detailing the scenarios, as well as their respective kinematics. All interactions were recorded in audio and video, where difficulties were observed both on the part of the instructors and of the students.

We conducted an evaluation of the SVETT with students from the Naval Academy to identify whether the use of the different resources available, in support of an instruction on the topological and tactical study of the terrain, responds to the hypotheses established at the introduction of this work. For each type of evaluation, a pilot test was conducted to verify possible failures and improvements, which was later discarded. As this was an instruction between theory and practice and they were having their first contact with the terrain, the students were not evaluated with grades by the instructors.

To this end, two scenarios were created for the students. In the first scenario, called "classroom scenario," they were inserted into a classroom on the operational study of the terrain using the simulator. In the second scenario, called "field exercise scenario," the study happened at a field exercise in the same classroom area. In both cases, each scenario lasted about 50 minutes. In the "classroom scenario," the instructor interacted with the students, leading to the use of the instructional resources available to transmit knowledge or resolve doubts. In this context, it was possible to observe their interaction with the application. At the "field exercise scenario," there were no changes in the instructor's usual resources. In the first scenario, 54 students participated in the activity and, in the second scenario, 30 students from those 54 who participated in the activity before.

The purpose of the created scenarios is related to the usefulness of the simulator as a tool to introduce the students to the basic study of the terrain even before their arrival at the place, despite the need to prove it as a method to settle the content. It should be noted that, after using the simulator to transmit the basic content, the subject addressed in the simulator, in theory, would no longer be seen, providing the exercises in real places with more advanced material to obtain a higher level of learning and consequently increase the FE quality.

In both scenarios, all students participated together in one class. Each participant, during the scenarios, by arriving at the experiment site, received initial instructions on the kinematics, and was invited to sign a consent form. After signing, the users were positioned in the place previously established for the experiment. Before starting the activities, they became familiar with the possible gestures and commands. In both scenarios, all participants received instruction from the same instructor, who followed a previously established curriculum.

After completing the first scenario instruction, the students were asked to fill out two questionnaires. The first one aimed to obtain knowledge about their experience as a student and experience in terrain study. The second one was about first impressions of the instruction with the system. For the second questionnaire of the "classroom scenario", we observed five questions with a Likert scale graduation from 1 to 7, where 1 and 2 are negative values, 3, 4 and 5 represent neutral values and 6 and 7 represent positive values; after that, we observed four questions with essay answers.

By the end of the second scenario instruction, the students completed two questionnaires. The first one was the "Student Satisfaction and Self-Confidence in Learning", translated to Portuguese by Almeida et al. (Almeida et al., 2015). For this questionnaire, the word "médico-cirúrgico" ("medical-surgical" in English) in question 7 and the word "clínico" ("clinical" in English) in question 8 were omitted to adjust the questions to the correct context. The second questionnaire was created to evaluate the concept of the instruction after the two scenarios were completed. For the questionnaires in the "field exercise scenario," we observe a Likert scale graduation from 1 to 5, where 1 represents negative values, 2, 3 and 4 represent neutral values and 5 represents a positive value. The next section shows the results and discussion.

**RESULTS AND DISCUSSION**

After the evaluations, this section analyzes the results obtained. With the responses, inferences were made to obtain information that confirms the system's contributions to the proposed problem. In addition, future works obtained from discussion will be proposed by the end of this work.

A total of 54 students participated in the first scenario, identified with the letter "P" followed by a number. Regarding questionnaire 1, which qualifies the participants, the students are aged between 20 and 24 years, with gender of 53 men and 3 women. In addition, they are taking the same course, where we have identified the standard of the target audience that will use the simulator for training. Therefore, the evaluations do not include people of advanced age or children, as they are not employed for activities related to the course. If the opportunity and need exist, new tests with a different target audience will be conducted.

Another detail is the fact that everyone is initially addressing this subject of the course, in which there is a predominance of the theoretical part, making it possible to use the simulator in the correct time frame, preceding the FE. Another aspect is the fact that most students have gone through two or no study regions, from which we infer that students have little or no experience in studying the terrain. Concluding the first questionnaire, 32 of the participants used virtual reality glasses between once a year and once a month and the others never used them, which denotes little or no knowledge or familiarity with VR simulators. On the answers to questionnaire 2 shown in Figure 2, which has a 0 to 7 Likert scale and evaluates the use of the tool in instruction, the question "conducting the BTS with the simulator" obtained an average of 4.28. The observation of the terrain had an average of 5.69. However, due to the lack of prior observation of the site and the little experience, we infer that this graduation is limited to the observation of a plot of land in a Virtual world, not being possible to compare it with the reality of the site. Considering these two values, we can infer also that there was a positive evaluation, despite the existence of some difficulty in observing the terrain. The last three questions obtained values above 6.37, from which we can infer a very positive acceptance for the use of the tool.

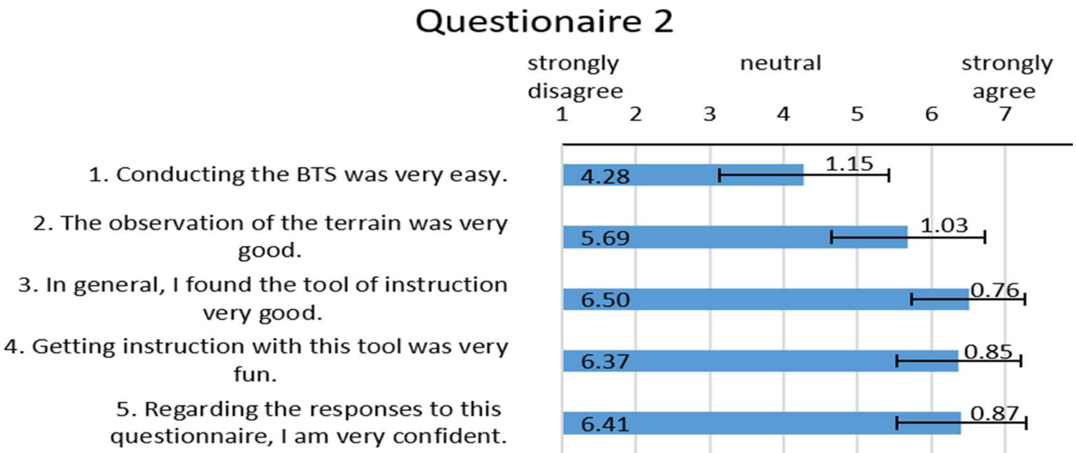


**Figure 2. Questionnaire 2 with mean and standard deviation answers using a Likert scale.**

About the essay questions, we can highlight as positive aspects the possibility of studying the area before being on it and the ease of studying the terrain with the simulator. As negative aspects, we highlight the low quality of the screen resolution, the low detail of the area and the short time learning at the simulator. Comparing the negative aspects highlighted with the previous answers, we can infer that the low screen resolution obstructed the terrain observation.

The "Student Satisfaction and Self-Confidence in Learning" has a Likert scale of 5 points and is divided into 2 subitems: "Satisfaction with Current Learning" and "Self-confidence in Learning". For the first subitem shown in Figure 3, the question "The teaching methods used in this simulation were helpful and effective." received a grade of 4.47, from which we can infer that the combination of the simulator and the field exercise study was positive.

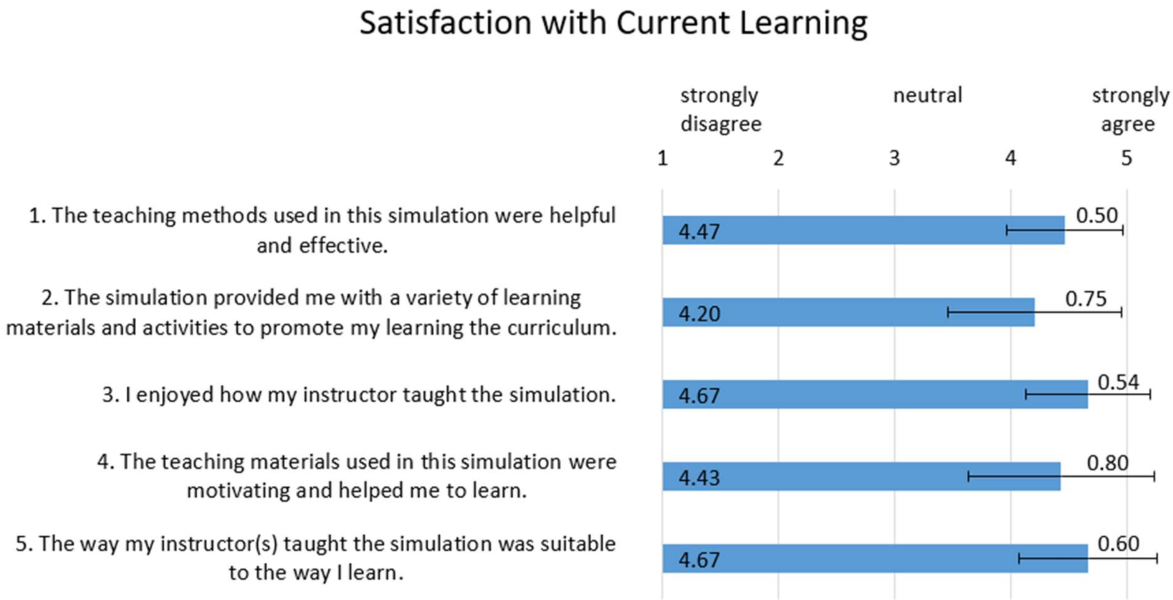


**Figure 3. "Student Satisfaction and Self-Confidence in Learning" answers for subitem "Satisfaction with Current Learning" mean and standard deviation answers with Likert scale.**

The question "The simulation provided me with a variety of learning materials and activities to promote my learning the curriculum." received a grade of 4,20. Combining that answer with the answer in questionnaire 2 "In general I found the tool of instruction…" (6,50 in a 7-point Likert scale), we can infer that the tools developed to support the instruction helped the students learn the subject.

About the grade of question 3: "I enjoyed how my instructor taught the simulation" (4,67), combined with question 5 "The way my instructor(s) taught the simulation was suitable to the way I learn" (4.67), we can infer that the instructor, in some way, learned how to explore the tools and got the students attention.

About answer 4: "The teaching materials used in this simulation were motivating and helped me to learn", we obtained a grade of 4.43. Considering all the answers of this subitem and the minimum grade obtained (4.20), since this questionnaire was applied after the field exercises, we can infer a positive result in the subitem "Satisfaction with Current Learning."

About the subitem "Self-confidence in Learning" shown in Figure 4, most grades were bigger than 4, except the question "I am confident that I am mastering the content of the simulation activity that my instructors presented to me", which received a grade of 3.57, the question "I know how to use simulation activities to learn critical aspects of these skills", which was graded 3.7, and the question "It is the instructor's responsibility to tell me what I need to learn of the simulation activity content during class time...", that received a grade of 3.97. By the fact that the field exercise was their second instruction, the second highest grade (4.50) was "I am confident that I am developing the skills and obtaining the required knowledge from this simulation to perform necessary tasks in a setting" and one of the negative aspects of questionnaire 2 was "short time learning at the simulator", we can infer that the time at the simulator was not sufficient for the students to feel more confident. On the other hand, the highest grade (4.70) was given to the question "My instructors used helpful resources to teach the simulation" (with the smallest standard deviation, 0.46), from which we can infer that the resources developed in the simulator helped the students in the teaching and learning process.

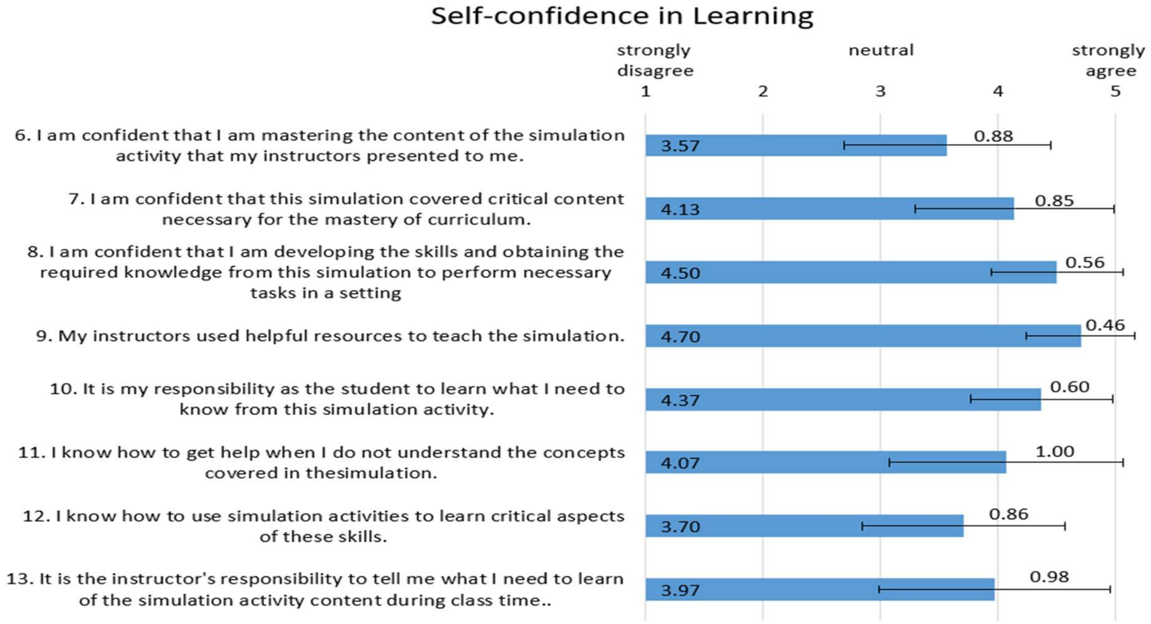


**Figure 4. "Student Satisfaction and Self-Confidence in Learning" answers for subitem "Self-confidence in Learning" mean and standard deviation answers with Likert scale.**

About the questionnaire 3 shown in Figure 5, which assesses the combination of classroom study and field exercise study, the question "I felt safer when I received the instruction in the field after having received the instruction through the simulator" (graded 4.69), combined with the question "The concept of instruction consisting of the use of the simulator followed by Exercise in the field in the same region of the simulator facilitated my learning." (graded 4.66 with the second smaller standard deviation 0.47) helps us to infer a positive answer to our main question: "Is it possible that the concept of a Learning Environment (LE) and resources usually seen in classroom can offer educational capabilities to better understand terrain analysis even before the presence in field?".

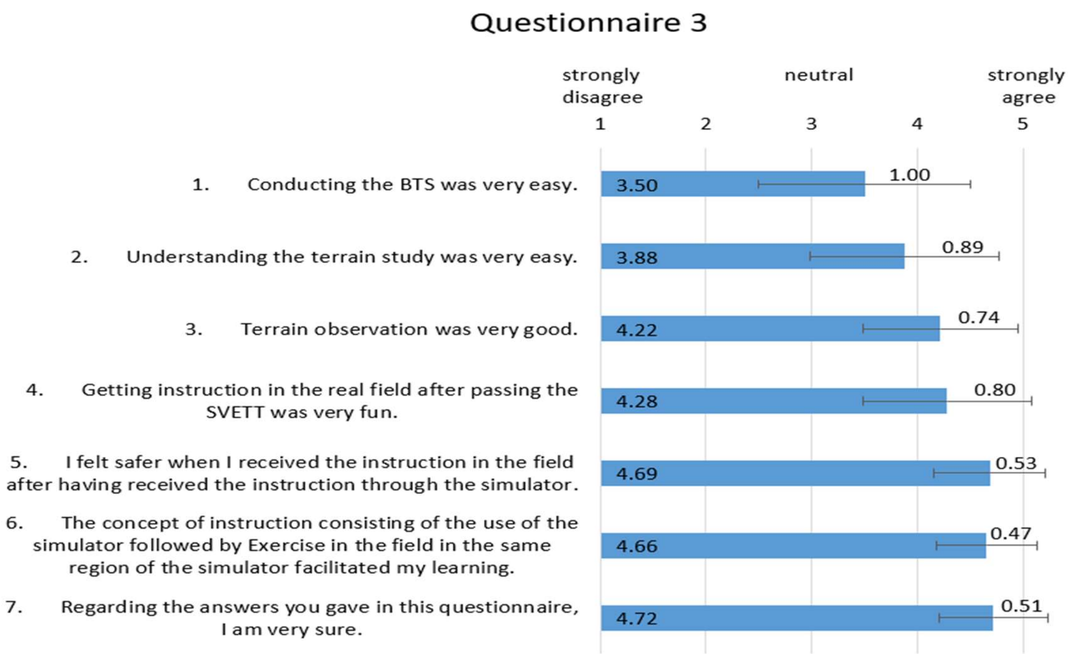


**Figure 5. Questionnaire 3 mean and standard deviation.**

## CONCLUSION

This work proposed the SVETT, a simulator that has resources usually used in classroom aiming to ease the transmission of knowledge by the instructor, as well as to unify the students' understanding using its tools. The concept that SVETT brings is that it is possible that a Learning Environment (LE) and resources usually seen in classroom can offer educational capabilities to better understand terrain analysis even before the presence in field.

We questioned that concept by evaluating it with 54 students in two scenarios. The first scenario occurred in a classroom, where the students received instructions about terrain study using SVETT. The second scenario happened at a field exercise, where the students received instructions without the classroom resources, in a usual way. After each scenario, they filled in two questionnaires each.

Discussing the results, we obtained higher grades (4.67 of 5.00) in questions like "I enjoyed how my instructor taught the simulation", and with "The way my instructor(s) taught the simulation was suitable to the way I learn". With those results, we inferred that the instructor, in some way, learned how to explore the tools and captivated the students' attention.

About the questionnaire that assesses the combination of classroom study and field exercise study, the students gave higher grades in questions like "I felt safer when I received the instruction in the field after having received the instruction through the simulator" (graded 4.69), and also with the question "The concept of instruction consisting of the use of the simulator followed by Exercise in the field in the same region of the simulator facilitated my learning." (graded 4.66 with the second smaller standard deviation 0.47), which helped us to infer a positive answer to our main question: "Is it possible that the concept of a Learning Environment (LE) and resources usually seen in classroom can offer educational capabilities to better understand terrain analysis even before the presence in field?".

About the essay questions, we could highlight as positive aspects the possibility of studying the area before being on it and the ease of studying the terrain with the simulator. As negative points, we highlighted the low quality of the screen resolution of one of the interfaces, the low detail of the area, and the short time learning at the simulator.

Building on these results, as future work, we aim to improve the terrain detail and resolution, enhancing some major points such as rivers and roads. Also, we look forward to evolving some other functionalities, such as time of the day, weather, visibility conditions, and so on. We also intend to evaluate the concept of this instruction with more advanced courses such as the Brazilian Marine Officers Advanced Course, the Amphibious Warfare Course, and the Infantry Sergeant Course, and incorporate objective human performance metrics in the next cycle of testing to better capture the Return on Investment (ROI) of SVETT.

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