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Empowering Students With Geospatial Solutions Through Challenge Based Learning

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EMPOWERING STUDENTS WITH GEOSPATIAL SOLUTIONS THROUGH CHALLENGE-BASED LEARNING

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ABSTRACT

Today, the field of Geospatial Solutions primarily focuses on spatial and mapping data, analysis, and technologies that primarily revolve around place and space. It is considered more as a tool or means rather than the ultimate objective of various interdisciplinary activities, where minimal attention is given to theoretical aspects, equations, and underlying principles of the subject. Conversely, despite advancements in science and technology and a broader audience for geospatial subjects, it is predominantly taught conventionally, disregarding the diverse needs and expectations of students. In recent years, there has been an exploration of innovative educational methods to utilize new pedagogical frameworks and enhance academic performance among students.
The present study aims to develop a framework and provide guidelines for the integration of Challenge Based Learning into Geomatics education. This framework consists of three interconnected phases: engage, investigate, and act. Subsequently, an educational pilot program is created and implemented to apply the designed

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framework to key topics such as food security and cultural heritage. Finally, the project refines the educational framework based on real pilot attempts and evaluation results, identifying potential issues and making necessary adjustments. The designed framework and the attained results are made publicly available for reference and utilization.

1 INTRODUCTION

The scientific and technological development witnessed in the last decades has radically changed the attitude to generating geospatial information, increasing the interest of scientists and practitioners from other domains like archaeologists, geologists, and ecologists. Related subjects are debated in a growing number of faculties, although in many cases, needs and expertise are different from pure geomatics courses. Geospatial information is seen as an “instrument” more than the final goal of their investigation: little, interest is given to theory, equations, and principles for the subjects.

Why CBL: Challenge-Based Learning aims at delivering education and knowledge by tackling and solving real-world challenges: teachers/mentors, stakeholders, and students are all involved in this process [1]. In the general CBL framework, stakeholders from the public, private, and non-profit sectors bring the real-world challenge, while students develop the technical solution thanks to the support of the mentors [2]. In this context, students acquire vital practical skills and discover how to apply academic knowledge in real-life scenarios that are usually not addressed in traditional education. This makes CBL especially appropriate for students from different disciplines seeking to learn about Geospatial solutions for tackling challenges in their respective domains.

Why Geospatial Solution: Geospatial solutions refer to all the data, knowledge, and technology used to acquire, handle, manipulate, process, and store geographical information. GIS, remote sensing, photogrammetry, and Global navigation systems are some related sub-topics here [3]. The added value of geospatial solutions is particularly evident in addressing Sustainable Development Goals and Global Challenges. However, The European geospatial analytics market is expected to develop at a rapid pace and is expected to grow at a Compound Annual Growth Rate (CAGR) of 14.92% over the forecasting period 2019-2027 (Europe Geospatial Analytics Market 2019-2027)[4].

Why CBL for Geospatial solution: Traditionally, Geospatial solutions are taught by providing detailed explanations of the underlying algorithms. While this approach is considered effective for training geomatics engineering, it may not align with the interests and expectations of students with limited experience in this field. In this context, CBL offers a valuable alternative by presenting education from a fresh perspective, integrating it with challenges that are more relevant to their studies. For instance, issues encountered in agriculture, geology, and cultural heritage can be redefined within this framework, making it easier for students to grasp and foster the development of innovative solutions through education.

The objective of this study is to provide guidelines for implementing Geospatial science education within a CBL framework. These guidelines are structured based on existing literature, discussions, and participation in workshops. Furthermore, the project refines the suggested educational methodology through a pilot course, allowing early identification of potential issues and offering a practical example to our community.

2 METHODOLOGY

The proposed methodology follows a general workflow consisting of five primary phases, as illustrated in Figure 1. The initial four phases are part of the framework development, where a versatile CBL-based educational framework is created. In the final phase, the framework is put into action, evaluated, and refined through a pilot implementation.

2.1 Engagement

In the engagement phase, the aim is to establish a connection between the students and the topic at hand. To achieve this, students are provided with the Big Idea and some initial guidance on transitioning from the Big Idea to Essential Questions. Throughout the Engage Phase, the focus shifts from a broad and conceptual Big Idea to a specific and actionable Challenge by employing the Essential Questioning process.

Essential questions, by nature, frame a topic as a problem to be resolved. They are open-ended inquiries that allow for multiple perspectives to provide answers. When formulating essential questions, it is crucial to take into account the viewpoints and requirements of stakeholders, as well as the predefined context [5].

In this phase, an elaborate document is created to facilitate students in understanding CBL (Challenge-Based Learning). Additionally, a comprehensive document is prepared for the Investigate phase, encompassing the concepts of Big Idea, Essential Questions, stakeholders, and challenges. Step-by-step instructions are provided to assist students in navigating through the CBL framework. Special attention is given to developing a detailed rubric to support students in the assessment process, which is both crucial and slightly intricate within the CBL framework.

- Phase input: The Big Idea, engagement phase guideline, assessment rubric
- Phase output: challenge proposal

2.2 Investigate

The investigate phase focuses on the collaborative efforts of all participants to address the challenge, leveraging their individual knowledge and skills, and considering what they are expected to gain from the experience. It involves planning activities that lay the foundation for actionable and sustainable solutions. The phase begins with guiding questions aimed at identifying the additional knowledge required to analyze and resolve the challenge. This phase acts as a bridge, transitioning from the challenge identified in the engage phase to the practical activities undertaken in the subsequent phase.

During this phase, the group members are tasked with addressing their defined challenge by seeking out relevant resources and activities that can assist them in gaining further information and knowledge directly related to the challenge. In practice, this phase encompasses three key components: Guiding questions, Guiding activities, and Guiding resources. These elements serve as a guide for the group members as they navigate through the investigative process.

For this phase guidelines and tables as well as rubrics are designed to help and support the students.

- Phase input: Challenge proposal, investigate step guideline, assessment rubric
- Phase output: Investigate phase report

2.3 Act

In the final phase, evidence-based solutions are formulated and put into action, drawing upon the findings derived from the Engage and Investigate phases. The act phase involves evaluating the results obtained and integrating the students' aspiration to make a meaningful impact or bring about innovation with their gained proficiency in understanding the big idea. This phase consists of three primary steps: solution concept, solution development, and implementation.

Solution concept: The investigation phase concludes with the establishment of a solid groundwork for the solution. In this particular step, the students will develop their plan to implement the solution. This step ultimately leads to the finalization of the solution concept.

Solution development: After the approval of the solution concept in the preceding step, the students will proceed with the development phase. Depending on the specific circumstances, they may be required to implement a code, conduct an experiment, administer a questionnaire, or create a prototype. Experiences encountered during this phase may prompt the students to revisit previous phases for revision, as necessary.

Implementation and evaluation: While the solution is developed, the students will continue with implementation. In this step, they need also to evaluate their solution, measure the outcomes, reflect on the results, discuss the findings, and report the failure or success process.

Throughout the Act phase, it is essential for students to maintain a continuous awareness of the previous phases. The results and findings obtained during this phase may give rise to new or modified guiding questions. As a result, the process becomes iterative, with this feedback loop serving to ensure that the solution remains efficient and has a meaningful impact on the challenge at hand.

Reflection, documentation, and sharing play crucial roles in CBL. It is important for students to document their experiences not only upon completing the implementation but also throughout the entire process. They should reflect not only on their own findings but also on the insights of others, if available. Once the implementation is finished and the results and findings are finalized, students are encouraged to share their work publicly.

- Phase input: Challenge proposal, Investigation document, assessment rubric
- Phase output: Implementation and findings sharing

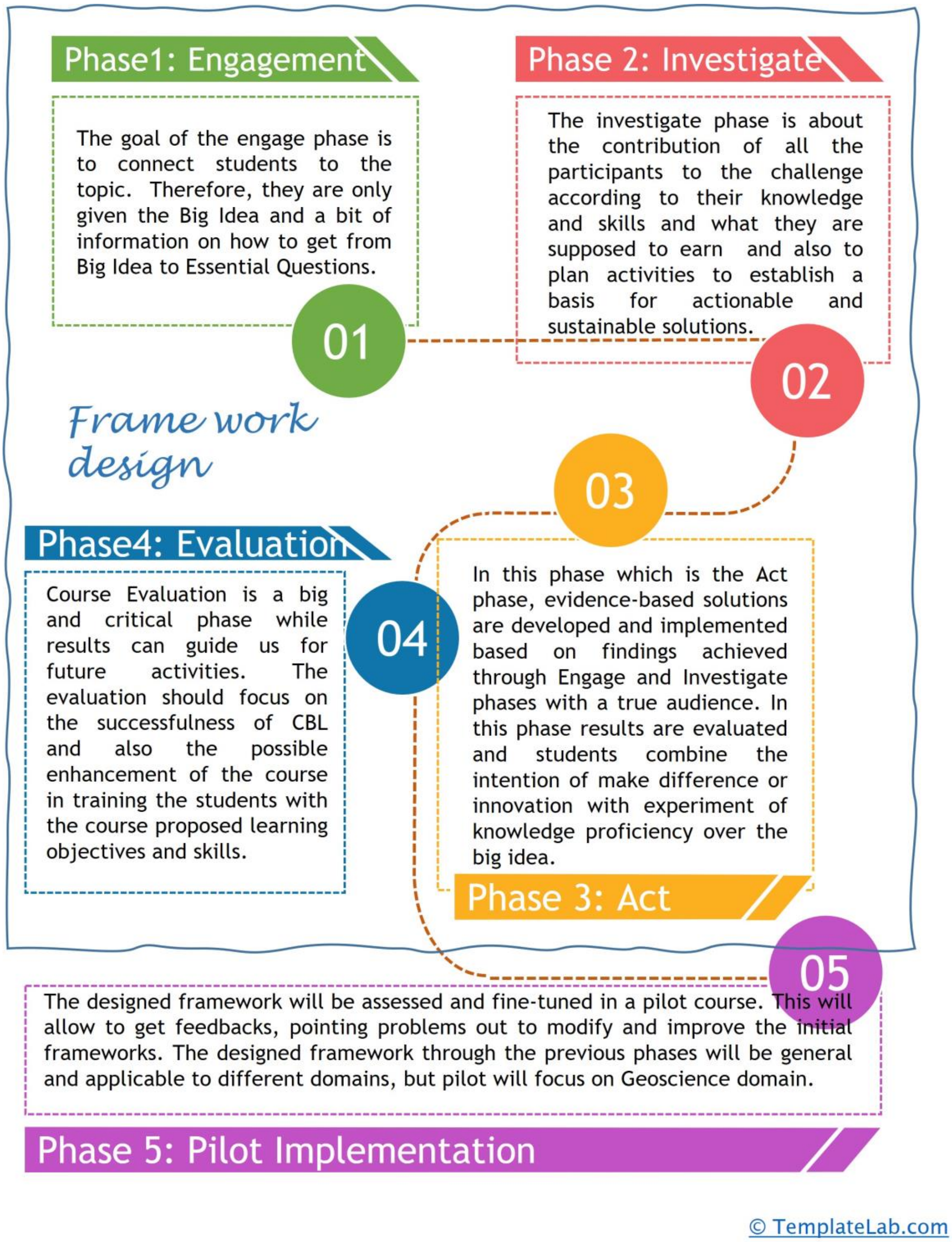

Fig. 1: Proposed CBL-framework strategy diagram.

2.4 Evaluation

The evaluation phase encompasses the assessment of not only the effectiveness of the newly designed CBL framework but also the accomplishments and contributions made throughout the project. As a result, the final evaluation strategy is developed during this phase, taking into account the following key elements:

- Evaluation of the new CBL framework using pre-designed questionnaires and via planning discussion sessions with all the people involved in the course.
- Evaluation of the whole course and comparing the results with those available from the previous years.
- For the evaluation, all the roles involved in the educational activities such as students, teachers, course coordinators, program coordinators, stakeholders, and supporting staff will be involved.

Dissemination, reflection, and feedback provision is the critical part of the project and will be handled in parallel with all the activities and modifications that will be considered respectively.

2.5 Pilot

To assess and evaluate the designed framework, pilot studies are required. In this particular phase, our focus is on UAV photogrammetry, an emerging technology with the ability to capture diverse geospatial data. Through the utilization of processing algorithms, the collected data can be analyzed, leading to the generation of valuable geospatial information. This information holds the potential to address various real-life multidisciplinary problems. However, many industrial and academic entities remain unaware of the potential benefits UAV photogrammetry offers in tackling their current challenges. Considering the flexibility, cost-effectiveness, wide availability, and capabilities of UAVs, they serve as practical and efficient platforms for data collection. Therefore, our study centers on UAV photogrammetry due to its significance. Furthermore, within the framework's scope, we also instruct a collaborative project focusing on the use of UAV photogrammetry for cultural heritage monitoring and documentation. This topic is selected as the Big Idea for our pilot study, considering its relevance to our educational program and the importance of food security.

3 RESULTS

The main purpose of this project is to design a framework based on CBL for teaching Geospatial concepts. For this purpose, five main phases are considered as discussed in the previous chapter. Here the experimental results are discussed.

For the first phase, the engagement document is designed. It has the intention of introducing the CBL concept to the students and motivating them on the advantages and added values of following such an educational framework. Then step by step guidelines are provided for them to follow. The main structure of the document is:

a) Introduction to challenge based Learning
b) Introduction to Big Idea
c) Introduction to Essential Question, Assignment 1: Essential Question

d) Introduction to Challenge Proposal, Assignment 2: challenge proposal
e) Assessment Rubric

The investigative document focuses on shaping the investigation activities of the students based on the main idea of CBL which is the importance of being involved with the real problem via actual stakeholders. The main structure of the designed document is composed of:

a) Introduction to guiding questions, factual and interpretative questions, Assignment 1: Guiding Questions
b) Introduction to guiding resources and activities, Assignment 2: Guiding resources and activities
c) Introduction to Analysis, Assignment 3: Analysis document
d) Introduction to Synthesis, Assignment 3: Synthesis document
e) Prepared forms for Guiding questions, activities, resources, analysis, and Synthesis
f) Assessment Rubric

For the Act phase, students are requested to carry out their projects. For this purpose, thy first are requested to conceptualize their proposed solution considering their investigation and engagement activities. Based on that, they will develop the solution and finally implement it in a way to address all the raised concerns and topics. The structure here is:

a) Introduction to Act phase; solution concept, solution development, solution implementation
b) Assignment: Act presentation

The evaluation phase is an integral part of this framework and is implemented during the pilot phase. The evaluation process primarily focuses on identifying the strengths and limitations of CBL, as well as encouraging students to reflect on their learning experiences through CBL. Specific questions are provided to assist students in comparing the CBL framework with their previous experiences in traditional knowledge-transferring educational settings. The evaluation phase aims to assess the added value of CBL and gather valuable insights from students' perspectives.

Moreover, evaluation is also needed to measure and weigh experimenting with CBL from an educator's point of view. Teachers, instructors, tutors, and stakeholders also experience different journeys of education where the feedback can help to improve the course and address the limitation. The main elements of this section are:

a) Evaluation form for the students
b) Evaluation form for the staff

The designed framework is implemented for educational purposes in two master courses, one at the University of Twente and the other at the University of Tehran. The primary objective is to apply the framework and make necessary modifications based on the lessons learned during the experimental phase. The mentoring team consists of a teacher, a local supervisor, and stakeholders. The teacher possesses experience in CBL, having participated in a pilot program while implementing her UTQ (University Teaching Qualification).

The pilot selected course A: For the implementation of the designed framework, a course that is embedded in MGEO master program in ITC faculty, University of Twente is selected. In this two-year Master's program taught in English, students will be equipped with the necessary skills to tackle a wide range of global challenges. These challenges include climate change, resource depletion, and pandemic diseases, which impact our society and vulnerable populations worldwide. Through the use of geo-information systems, students will learn how to effectively address these issues.

Throughout the program, students will gain theoretical knowledge, technical proficiency, and competencies in big data analytics. They will learn how to locate and access relevant data, analyze complex problems, visualize data, and develop innovative and sustainable solutions. With their newfound expertise, students will contribute to advancements in various domains such as food and water security, management of natural resources, geo-health, adaptation to climate change, urban development, and smart cities, disaster risk reduction, and responsible land administration.

The course is offered in the third quartile of the first year. During the first quartile, they learn the basics of Geo-Information Science and Earth Observation. The second quartile is dedicated to two courses from the specialization each has chosen.

It consists of two components; the first component introduces the students to a set of key global challenges which have been recognized internationally through keynote lectures and associated working groups. The second component of the course is a multidisciplinary and project-based investigation in interdisciplinary teams. With their project team, students will analyze a global issue more in-depth, and collaboratively design a response at the local level. The CBL pilot is implemented for the second component of the course.

A group of three students from the selected course is chosen for this pilot. These students are tried to be selected diversly based on their background and individual topic of interest. Moreover, for the group, a CBL-aware mentor, a local supervisor, and an external advisor are considered to support students during their projects.

The practice started with the initial introduction of CBL to the students. The CBL educational program is something new not only to the students but also to lots of teachers. Then the program is continued by asking the students in the same group to start talking and getting to know each other. The students are requested to talk more friendly about themselves and to get closer. This discussion will help them to know each other more closely and it can help them to decide about their future roles in the assignment. For these students, food security is considered their Big Idea.

The pilot selected course B: In the second pilot, jointly with the University of Tehran the designed CBL framework is tested for master students of Conservation of Cultural Property under the topic of UAV Photogrammetry for cultural monitoring.

Recognizing the demand for architects who possess expertise in both research and practice and acknowledging the aspirations of numerous architecture graduates to pursue further education in postgraduate and Ph.D. programs, the University of Tehran, the oldest university in Iran, initiated its part-time Master's program in 2002. This program admits approximately twenty students annually. In order to enhance the quality of architectural education, the program offers diverse design studios, each focusing on a specific theme. The Interior Architecture program was the first to be introduced in 2010, with an annual intake of around fifteen students.

The objective of this course is to let the students explore and practice the application of photogrammetry for cultural heritage studies. For this purpose, students are educated with basic concepts of photogrammetry and 3d modeling based on 2d images and computer vision-based processing methods. After learning enough about photogrammetric-based concepts, students are taught about UAVs as agile and flexible platforms for data acquisition that are playing an important critical role in today’s Earth Observation science.

While the theoretical part is done, students together with their teaching team attended a real pilot on a UAV-based photogrammetry project and practiced the whole procedure from image acquisition to product generation. At this time when students are familiar with the concepts of UAV photogrammetry, they are requested to investigate and study its capabilities for their own discipline. For this purpose, the big idea is defined for them as UAV Photogrammetry for Cultural Heritage Monitoring.

Attendance composed of three master students all with backgrounds in architecture and cultural heritage documentation. The same strategy as course A is considered to prepare students with the concept of CBL and to guide them during the CBL trajectory. The whole developed framework including forms, guiding documents, presentation, and tables are presented openly and available to those who are interested via the project web page[4]. Moreover, sample results of conducted pilots as well as the evaluation and assessment results are also published. For sure the personal privacy concerns of the attendances are considered.

It is obvious from the achieved results that the CBL experience looks appealing mostly to the students and they found it a valuable educational methodology to be involved in. On the other hand, the teaching team is not so comfortable with this experience which might be due to two main concerns. Experiencing a new methodology is most challenging for the academic staff. Moreover, CBL enjoys a larger amount of freedom and flexibility rather than traditional education which is its advantage and at the same time can cause concerns for team leaders.

[4] https://www.itc.nl/global-impact/itc-major-projects/!/cbl4uav

4 SUMMARY AND ACKNOWLEDGMENTS

This project aims at the framework development for conducting educational activities based on adopting Challenge-Based Learning and developing that for master course implementation in Geomatics Engineering. The framework is designed and it is openly published and accessible through the project web page. Some key findings from the executed pilots can be summarized:

- Students mostly found the CBL practice more time-consuming than their previous normal knowledge-transferring experiences
- Students believe more effort is needed to handle CBL and more team working involvement is desired
- They found CBL more promising in providing them with the practical knowledge and skills they are supposed to learn after attending the theoretical part of the course
- Students at these course pilots mostly prefer CBL to the normal education
- Students find CBL less successful in course content knowledge provision
- Staffs find the assessment part of the CBL the most challenging issue
- Staffs find their role at CBL more supervisory than normal education
- Staffs believe CBL is more successful than normal education for the practical part of the courses and they are not sure if it can be a good replacement for knowledge transferring in traditional education

Assessing students in CBL educational courses can be a challenging task, particularly when it comes to grading. On one hand, we need to evaluate students based on the established learning objectives of the course, which is similar to conventional assessment practices. However, on the other hand, the active involvement of students in the challenges presented in CBL requires additional assessment considerations. This is because participating in these challenges demands significant time, effort, and energy from the students. As a result, there is a need to place greater emphasis on developing assessment protocols for future studies in order to address these unique aspects of CBL.

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