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DEVELOPMENT OF METHODOLOGY FOR GIS ASSIGNMENTS IN FLOOD MAPPING USING BLOOM'S TAXONOMY AND SCAFFOLDING APPROACH

Abstract: This paper presents a study on designing and implementing a series of GIS assignments for an educational course on flood mapping, structured using Bloom's Taxonomy and the scaffolding teaching method. Geographic Information Systems (GIS) education often involves the acquisition of complex technical skills, requiring a structured learning approach to ensure a progressive mastery of concepts. In this study, a sequence of practical assignments was developed at increasing levels of complexity corresponding to Bloom's cognitive levels, from basic knowledge acquisition to higher-order evaluation tasks. The scaffolding approach was utilized to facilitate student learning, wherein extensive guidance was provided in early tasks and gradually removed in later ones as students gained competence. The research was conducted in an upper-level undergraduate course, "Methodology for Mapping Flood Emergency Areas", at the Sarsen Amanzholov East Kazakhstan University, with 21 enrolled students. The assignments integrated real-world flood mapping scenarios using GIS tools such as ArcGIS Pro and QGIS, enabling students to apply theoretical knowledge in practical settings. Results from the study indicated that a structured, scaffolded approach significantly improved student performance and confidence in GIS skills. Quantitative analysis of assignment grades showed steady improvement as students progressed to more complex tasks, while qualitative feedback revealed high engagement and perceived learning value. The findings underscore

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the effectiveness of combining Bloom's Taxonomy with scaffolded instruction in GIS education, providing a practical framework for curriculum design. This approach has the potential to enhance learning outcomes in technical subjects, particularly in geospatial analysis, and offers recommendations for educators on implementing scaffolded assignments effectively. Further research could explore long-term skill retention and the application of this methodology in other technical disciplines.

Keywords: Bloom's Taxonomy, GIS Education, Scaffolding Approach, Flood Mapping, Geospatial Analysis, Technical Skill Development, Higher-Order Thinking, Educational Assignments, Spatial Data Interpretation, Learning Progression

Introduction

Geographic Information Systems (GIS) education often involves teaching complex, technical skills that require careful progression. In courses such as 'Methodology for mapping areas of emergency situations' – where students must learn to analyze geospatial data, interpret different models, create hazard, vulnerability and risk maps – a structured approach to assignments is crucial. Well-designed assignments can guide learners from fundamental concepts to advanced analysis in a stepwise fashion, ensuring they build the necessary foundation before tackling more complex problems. Educational research offers frameworks to achieve this progression. Bloom's Taxonomy is a widely used framework for categorizing learning objectives into levels of cognitive complexity [1], [2]. It defines six cognitive levels – Knowledge, Comprehension, Application, Analysis, Synthesis, and Evaluation – ranging from basic recall of information to high-level critical thinking and creation. By aligning course tasks with these levels, teacher can ensure a balance between lower-order and higher-order thinking skills [3].

Another key pedagogical concept is instructional scaffolding. Scaffolding is the process of providing temporary support to students as they learn new skills, then gradually removing those supports as students become more proficient [6], [7].

This method, rooted in learning theory, allows students to build on prior knowledge and gain confidence step by step. In practice, scaffolding might involve guided tutorials, hints, or simplified sub-tasks early on, which are phased out as learners progress. The combination of Bloom's Taxonomy with scaffolding strategies is especially relevant in GIS education, where mastering software and spatial analysis can be challenging for beginners. By structuring learning activities from simple to complex and providing guidance at each stage, teachers can help students go through Bloom's hierarchy effectively [8], [9], [10].

In other words, assignments that start with fundamental knowledge and advance toward evaluation can be scaffolded such that each level prepares students for the next, gradually increasing the complexity of tasks and questions.

This study explores the development of a series of GIS assignments for a flood mapping course using these pedagogical approaches. The main goal was to improve student learning outcomes by carefully sequencing assignment activities according to Bloom's cognitive levels and applying scaffolding techniques throughout the whole process. In order to achieve the goal, the following objectives were set: providing literature review, describing the course design and methodology for integrating Bloom's Taxonomy and scaffolding, detailing the assignments created at each learning level, and evaluation of the results in terms of student performance, engagement, and feedback. The importance of a structured, scaffolded approach in GIS education was discussed, and recommendations were made for teachers on how to implement similar strategies.

Bloom's Taxonomy has long been used to design curricula and assignments that promote deeper learning [11],[12]. The hierarchy from knowledge to evaluation encourages educators to push students beyond rote memorization toward analysis and critical thinking [13], [14].

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In GIS education, where students must not only recall facts but also apply techniques to solve spatial problems, this framework is particularly valuable. In [15] it is noted that Bloom's Taxonomy provides an influential guide for creating and teaching GIS content, ensuring that learning objectives address a range of cognitive skills. Recent studies have applied Bloom's Taxonomy in geospatial learning contexts. For example, in [16] a digital GIS portfolio model was implemented in courses of the universities in Finland that explicitly followed Bloom's levels [17]. Students engaged in progressively more demanding, inquiry-based GIS activities, from basic map readings to complex spatial analyses. The results were positive: the structured progression improved student competence in using GIS, increased their motivation to learn, and heightened their awareness of the importance of GIS. This suggests that aligning GIS assignments with Bloom's cognitive levels can lead to gains in both skills and enthusiasm. Bloom's framework offers a clear set of steppingstones for designing educational tasks, and its use in GIS courses can ensure that students systematically advance to higher-order thinking tasks such as spatial analysis and decision-making.

Scaffolding as a teaching technique has been widely studied for its benefits in supporting student learning, especially in complex or technical subjects. The core idea is to remove support over time – teacher initially provide substantial guidance and structure, then withdraw assistance as learners develop knowledge and skills [4], [5]. This approach aligns naturally with Bloom's incremental levels, as simpler tasks can be heavily guided and advanced tasks require more student autonomy [8].

In digital learning environments, scaffolding can take the form of step-by-step tutorials, template files, automated hints in software, or forum support for students working on projects. In [18], [19] it was demonstrated that a web-based scaffolding GIS strategy for teaching spatial planning in a distributed environment is quite an efficient method. This approach supported architecture and design students in using GIS for site selection by providing a collaborative online platform with scaffolding mechanisms. The study found that this digital scaffolding model improved students' understanding of spatial planning processes and enhanced their metacognitive awareness in problem-solving [6]. In other words, when students had structured support within a GIS task, they were better able to plan and complete complex spatial analyses, even in an online setting.

Research in higher education also supports the efficacy of scaffolded instruction in GIS. In [20], [21] an action research study was conducted in a university GIS course that integrated scaffolded field exercises involving GPS and GIS technologies. The scaffolded instruction was evaluated by examining student work and perceptions. The findings indicated that students were able to transfer their GIS/GPS skills to independent projects and real-world field settings after undergoing scaffolded training [20]. This means that when students learned GIS concepts through a guided, stepwise approach, they not only mastered the content but could also apply their skills effectively beyond the classroom. A very recent study [16] on creating StoryMaps (a narrative GIS mapping project) across various education levels provides evidence of scaffolding benefits. It was concluded that the process of building StoryMap projects serves as an effective scaffolding approach for geography and GIS education and leads to strong student retention of knowledge [16]. However, researchers also emphasize that this is true only if the learning activities are designed with clear objectives and assessments in mind to guide students through the scaffolded experience. This highlights that while scaffolding can empower students, it should be coupled with transparency in expectations and criteria for success.

The combination of Bloom's Taxonomy and scaffolding in assignment design reflects broader best practices in education. Educational design literature recommends sequencing assignments from simpler foundational tasks to more complex ones as a way to scaffold learning effectively [23]. Each assignment in a sequence should build upon skills from the previous one, so that students develop discrete competencies before moving to the next level of difficulty. For instance, a student might first learn core concepts and terminology (simple task), then practice applying those concepts in a structured exercise, and finally undertake an open-ended project that integrates and extends their learning. By structuring coursework this way, no assignment is isolated; instead, each serves as a steppingstone that prepares students for subsequent challenges. This strategy has been shown to keep students more engaged and reduce cognitive overload, since learners are not expected to perform complex tasks without the necessary prior practice. Moreover, aligning each assignment with a specific cognitive level or learning outcome ensures that assessment is meaningful. Assignments targeting higher-order skills (analysis, synthesis, evaluation) often involve project-based or inquiry-driven work, which is supported by prior tasks targeting lower-order skills (knowledge, comprehension) [22].

In summary, the [23] suggests that to maximize learning, instructors should design a scaffolded sequence of practical assignments that gradually increases in complexity and cognitive demand. This approach is particularly beneficial in GIS and other technical fields where students must acquire both conceptual understanding and procedural skills. The present study builds on these principles, using Bloom's Taxonomy as a scaffold for curriculum design and implementing assignment sequences to incrementally develop students' flood mapping expertise.

Methods and Materials

The study was conducted in an upper-level undergraduate course 'Methodology for mapping flood emergency areas' on the topics focused on flood mapping using GIS, with an enrollment of 21 students. The course lasted a full semester and was part of a geography program in the Sarsen Amanzholov East Kazakhstan University. The instructional design followed an outcome-based approach, where specific learning objectives were defined for each module of the course. In order to facilitate a structured learning progression, the course was organized around three tiers of assignments – beginner, intermediate, and advanced – corresponding roughly to the lower, middle, and higher levels of Bloom's Taxonomy. In practice, six assignment activities were developed and each corresponded to one of Bloom's cognitive levels (Knowledge, Comprehension, Application, Analysis, Synthesis, Evaluation). These assignments were sequenced so that they built upon one another, reflecting a scaffolding strategy. Early in the semester, beginner-level assignments addressed basic knowledge and comprehension outcomes, ensuring students had the necessary grounding in GIS concepts and flood data. Mid-semester assignments moved to application and analysis, requiring students to apply their learning to solve problems and interpret data. Finally, end-of-semester advanced assignments involved synthesis and evaluation, where students had to integrate multiple skills and make judgments about flood mapping results. By aligning tasks with Bloom's levels in this manner, the course ensured a deliberate increase in cognitive complexity and skill requirement as students progressed.

The proposed course pedagogical methodology includes the following interrelated components, including methods, models, tools and conceptual framework. The interaction of these elements is presented in the course conceptual diagram (Fig 1).

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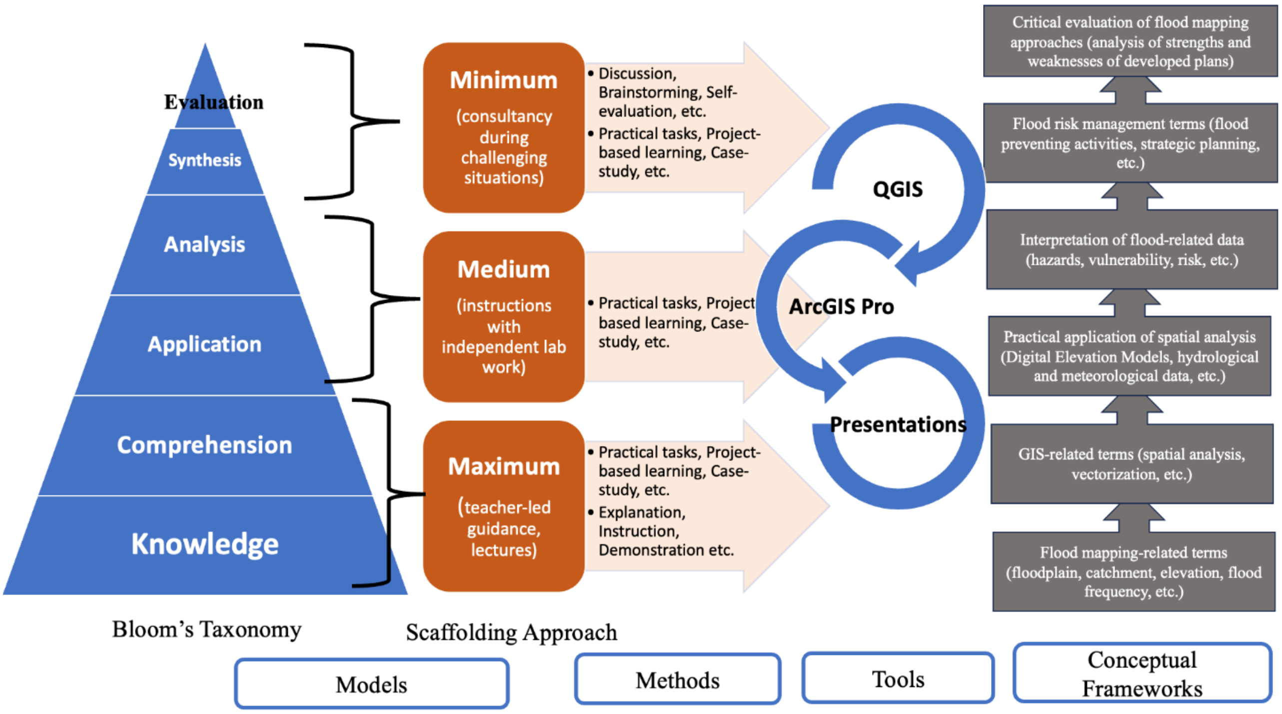

Figure 1. Conceptual diagram of the methodology demonstrating interaction between Bloom's Taxonomy and the Scaffolding Approach in the course devoted to studying methods for mapping flood emergency zones

The methodology was based on progressively increasing the complexity of educational assignments following two combined pedagogical models: Bloom's cognitive taxonomy levels and scaffolding approach (Table 1). A variety of methods were used to develop the Assignment activities for the course, but the core of the proposed methodology was project-based learning and case-study. They contributed significantly to the formation of the applied nature of the course and its focus on studying regional problems of Eastern Kazakhstan.

Geographical information systems (ArcGIS and QGIS) were used as specialized tools in the course for a significant improvement of its analytical part, allowing the use of spatial analysis and modeling methods.

Table 1. Matching assignment activities and scaffolding supports on the basis of Bloom's taxonomy used in 'Methodology for mapping flood emergency areas' course

No.	Bloom's taxonomy level	Assignment activities	Scaffolding supports
1	Knowledge	Recalling definitions, recognizing map elements	Maximum (teacher-led guidance, lectures)
2	Comprehension	Explaining concepts, interpreting maps	Maximum (teacher-led guidance, lectures)
3	Application	Performing basic mapping tasks	Medium (instructions with independent lab work)
4	Analysis	Examining data relationships and patterns	Medium (instructions with independent lab work)
5	Synthesis	Creating a new integrated flood analysis	Minimum (consultancy during challenging situations)
6	Evaluation	Critiquing results and decision-making	Minimum (consultancy during challenging situations)

Bloom's Taxonomy provided the cognitive framework for assignment design, while scaffolding informed the instructional support given at each stage. At the outset of each assignment, learning objectives were stated using action verbs appropriate to the Bloom level (e.g., "list" or "identify" for Knowledge, "analyze" for Analysis, "evaluate" for Evaluation). The content and deliverables of the assignment were then designed to meet these objectives. To implement scaffolding, the level of instructional guidance was calibrated according to the assignment difficulty. In the beginner (foundational) assignments, which correspond to Knowledge and Comprehension levels, students received extensive guidance. Detailed step-by-step instructions were provided for using the GIS software (ArcGIS Pro and QGIS), including screenshots and example commands. Worksheets with partially completed examples were given to help students learn basic operations like georeferencing, vectorization, creating and adding specific data layers and etc. These supports acted as the "scaffold" to hold up novice learners [4], [5].

In the intermediate assignments (Application and Analysis levels), the scaffolding was moderate. Students were given general guidelines and templates, but fewer step-by-step hints. They were expected to recall and apply techniques learned earlier to new datasets (e.g. performing a spatial overlay or running an elevation analysis to identify flood-prone zones). Instructors remained available for questions, but students were encouraged to attempt problem-solving on their own or with peers.

During the advanced assignments (Synthesis and Evaluation levels), most explicit supports were removed. These tasks were more open-ended, providing a scenario and data but leaving the approach to the student. For instance, the final group task was to develop a flood hazard map and risk assessment for East Kazakhstan region with minimal procedural instructions, thereby requiring them to decide on appropriate GIS tools and workflow.

Throughout the process, the teacher monitored students' progress and provided feedback, effectively acting as a safety net in case the absence of scaffolding in advanced tasks proved too challenging. This approach ensured that students always had the necessary prerequisite knowledge and skills before encountering the next level of difficulty, embodying the idea of scaffolding instruction by introducing more complex tasks and questions as students' progress through the taxonomy.

The assignment sequence was structured to reflect both Bloom's hierarchical levels and a practical flood mapping workflow. Table 1 summarized the alignment between Bloom's levels, assignment activities, and scaffolding supports. Assignment 1 targeted Knowledge (recalling definitions, recognizing map elements); Assignment 2 targeted Comprehension (explaining concepts, interpreting maps); Assignment 3 focused on Application (performing basic mapping tasks); Assignment 4 on Analysis (examining data relationships and patterns); Assignment 5 on Synthesis (creating a new integrated flood analysis); and Assignment 6 on Evaluation (critiquing results and decision-making). These were divided into three broad phases: beginner (Assignments 1–2), intermediate (Assignments 3–4), and advanced (Assignments 5–6). Each phase corresponded to a level of student autonomy. During the beginner phase, class sessions were more teacher-led and tutorial-driven (high instructor involvement). The intermediate phase shifted to a mix of instruction and independent lab work. The advanced phase largely consisted of project work with the teacher as a consultant. Notably, while scaffolding was intentionally designed to disappear, the importance of not abandoning support entirely was recognized in order to finish the final project successfully. When a student or the class as a whole struggled with an advanced task, the instructor intervened with a mini-review or hint, proving findings that even in self-directed stages, a teacher-centered approach is sometimes crucial [16], especially for teaching GIS skills. This balance prevented students from becoming lost or frustrated while still maintaining high expectations at the advanced levels.

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Both quantitative and qualitative evaluation methods were applied in order to assess the effectiveness of the Bloom's Taxonomy-based scaffolding approach. Student performance data on each assignment and on the overall course outcomes were analyzed. Each assignment was graded using a rubric aligned with its learning objectives (for example, the analysis assignment was graded on criteria such as accuracy of analysis and interpretation of results, reflecting the Analysis cognitive level). Metrics such as the class average score for each assignment, the distribution of grades, and how many students met or exceeded competency on first attempt versus after feedback, were tracked. Performance on early assignments to that on later assignments to observe improvements in skills were compared. In addition, a summative test at the end of the course included components at various Bloom levels to measure knowledge retention and higher-order thinking; results from this exam provided another quantitative measure of learning gains throughout the course. Qualitatively, data on student engagement and perceptions were collected. This was done through a post-course survey and a focus group discussion. The survey included open-ended questions asking students to reflect on their learning experience, the difficulty of assignments, and the usefulness of the scaffolding approach (e.g., "Did the step-by-step progression of assignments help your learning? Please explain."). The focus group, conducted with a volunteer subset of students, allowed for more in-depth feedback and discussion of what aspects of the assignments were most and least helpful. We also collected informal observations during the course – for instance, noting the frequency and type of help requests during labs, and the level of student interaction or collaboration observed. By using this mixed-methods evaluation design (an approach similar to that of [16] where a mix of quantitative and qualitative methods to evaluate student learning experiences were used [5], current research was aimed to capture both objective improvements in performance and subjective student experiences. This comprehensive evaluation strategy helped in assessing not only what the students learned, but also how they learned and felt throughout the scaffolded assignment sequence.

To assess the effectiveness of the scaffolded instructional approach, we conducted a comparative statistical analysis between the scaffolded group and a control group that completed equivalent assignments in a prior iteration of the course without scaffolding. For each assignment aligned with Bloom's Taxonomy levels, we calculated descriptive statistics including the mean and standard deviation of student scores for both groups.

We then applied independent two-sample t-tests to determine whether the observed differences in mean scores between the scaffolded and control groups were statistically significant. This test was appropriate given that the two groups were independent, and the data approximately followed a normal distribution. A p-value of less than 0.05 was considered statistically significant.

To assess the magnitude of observed differences, we also computed Cohen's d as a measure of effect size. Values of d around 0.2, 0.5, and 0.8 were interpreted as small, medium, and large effects respectively, according to conventional benchmarks.

Results

The main result of the research is the system of assignments developed for each cognitive level of Bloom's Taxonomy, followed by the description of scaffolding techniques used. The context for all assignments was a real-world scenario of flood mapping, using authentic data and GIS tools. The sequence of assignments was as follows: Knowledge Level – Flood Mapping Fundamentals, Comprehension Level – Understanding Flood Data and Maps, Application Level – Basic GIS Flood Map Creation, Analysis Level – Analyzing Flood Risk Factors, Synthesis Level – Creating an Integrated Flood Management Plan, Evaluation Level – Critiquing and Presenting Flood Map Results.

Knowledge Level – Flood Mapping Fundamentals.

The first assignment's objective was designed to address the Knowledge level, where students recall and recognize basic facts and concepts. The learning objectives were that students would be able to define key terms in flood mapping and identify basic components of a GIS flood map.

In this introductory assignment, students received a glossary of essential terms (e.g. floodplain, catchment, elevation, flood frequency) and a simple printed flood hazard map of a region. The tasks included: (1) listing definitions of the key flood-related terms in their own words, and (2) labeling elements on the provided flood map (such as the legend, scale bar, flood zones, etc.). Students were also asked to identify various data layers commonly used in flood mapping (for example, river networks, rainfall data, digital elevation models) from a given description or screenshot. This part was essentially a low-stakes quiz embedded in the assignment, checking their ability to recognize components of GIS data.

Due to the fact that it was a beginner-level task, strong scaffolding support was provided. The teacher gave a short tutorial reviewing the terms and demonstrating how to read a flood map. Students were provided with an example of one term defined and one part of the map labeled, to illustrate the expected answers. Additionally, a list of guiding questions was given (e.g., "What is the definition of a 100-year flood?" – expecting recall from course readings). These supports ensured that even students with no prior GIS background could successfully recall or locate the information. By completing Assignment 1, students solidified foundational knowledge. This prepared them for the next level, as they would need to understand and explain these concepts in context rather than just recall them.

The scaffolded group scored higher on average (mean ≈ 88.8%, SD ≈ 5.9) than the control group (mean ≈ 78.2%, SD ≈ 5.1). An independent two-sample t-test confirms this difference is statistically significant ($p < 0.001$). The effect size is very large (Cohen's d ≈ 1.9), indicating the scaffolded approach substantially improved Knowledge-level performance.

Comprehension Level – Understanding Flood Data and Maps

The second assignment targeted Comprehension level. Students demonstrated understanding by explaining concepts and interpreting information from flood data and maps. The objectives included explaining the significance of various flood map features and summarizing the relationship between rainfall and flooding in a given scenario.

In this task, students were given a short case study of a past flood event in the East Kazakhstan region (including background data such as precipitation records and a flood extent map for that event). The teacher asked students to answer questions that tested their understanding, for example: Explain what the different colors on the flood hazard map represent and why certain areas are marked as high-risk.' Another question was: Given the rainfall data for this event, describe how rainfall intensity is related to the flooded area extent.' Students also had to write a short paragraph summarizing the sequence of events that led from heavy rainfall to flood inundation, demonstrating comprehension of the process. Essentially, they were required to interpret the map and data and explain them in words. This goes beyond listing facts; it checks if they grasp what the facts mean.

In order to provide scaffolding support to comprehension level assignments, the teacher prepared a structured worksheet for the case study. The worksheet broke down the interpretation process into steps: first, identify what each map symbol means (recalling knowledge from Assignment 1), then describe patterns observed (e.g., "the low-lying areas in blue correspond to the floodplain"), and finally, connect those patterns to underlying concepts ("these areas are flooded because they are at lower elevation and near the river"). Sentence starters were provided to help students frame their explanations (for instance: "The blue shaded area indicates…, which suggests that…"). Students also discussed the case in small groups during class,

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allowing them to articulate their understanding verbally before writing it down. By the end of Assignment 2, most students were able to articulate the 'why' and 'how' of flood mapping basics, not just the 'what'. This comprehension was crucial for the upcoming application-level task, since students would be asked to create maps using similar data.

The scaffolded group's mean (≈ 85.2%, SD ≈ 4.9) was slightly higher than the control's (≈ 82.7%, SD ≈ 6.1), but this small gap (≈2.5 points) was not statistically significant (t-test p ≈ 0.16). The effect size was small-to-moderate (d ≈ 0.45). Thus, at the Comprehension level, both groups performed similarly, and scaffolding yielded no clear advantage.

Application Level – Basic GIS Flood Map Creation

The third assignment moved into Application level. Here, students needed to apply their knowledge to perform a straightforward GIS task: creating basic flood maps. The objective was that each student would be able to use GIS software tools to generate flood maps from given data, following a set procedure. In this hands-on assignment, students were provided with a dataset for a hypothetical flood scenario. The data included a Copernicus digital elevation model (DEM) of the East Kazakhstan region, non-digitalized topographic map with detailed river channels in it, and precipitation and hydrological records from RSE Kazhydromet. The task was to use the GIS software (ArcGIS and QGIS) to identify areas likely to flood given the precipitation amount and various hydrological data. Concretely, the assignment steps involved: loading the DEM and digitalized river data into the GIS, executing a simple spatial analysis (e.g., delineating the watershed or running a terrain analysis to find low-lying areas), and then combining this with the rainfall and hydrological data to highlight zones that might be inundated (for instance, all areas below a certain elevation threshold near rivers). This assignment required them to recall what they learned (from Assignment 1 and 2) and do something with it in the software environment. It was a relatively structured lab exercise but demanded active application of skills rather than just observation or description.

While this was a more complex task than the previous ones, scaffolding was still present but in a reduced form. Instead of full step-by-step instructions, students received a general workflow outline. For example, the assignment sheet listed the major steps (data import, analysis, map visualization) but did not tell them every menu click or command. A short in-class demonstration was given by the teacher to show a similar process (using a different dataset as an example), and a reference handout of common GIS functions was available. During the lab session, students could consult with the teacher if they got stuck on a technical step. The idea was to encourage independent execution while still providing support resources. Through this assignment, students practiced applying concepts like "high level of precipitation leads to flood in low areas" in a tangible way. Completing it successfully indicated that they could use GIS tools to implement theoretical knowledge. This practical skill development was essential before moving on to more open-ended analysis in the next assignment.

The scaffolded cohort averaged 79.1% (SD ≈ 4.4) versus 69.8% (SD ≈ 8.9) in the control group. This ~9.3-point difference was statistically significant ($p < 0.001$). The effect size was large (d ≈ 1.3), suggesting a meaningful improvement in Application-level scores due to the scaffolded approach.

Analysis Level – Analyzing Flood Risk Factors

The fourth assignment was aimed at the Analysis level. Students were required to examine data critically, identify patterns, and draw connections between different pieces of information. The objective was to have students analyze multiple factors contributing to flood risk in an area and derive meaningful insights (understanding how land use and population distribution affect flood impact).

For this analytical task, students were provided with a richer dataset and a more complex problem scenario. The dataset included layers such as: land cover (showing urban, forest, agriculture areas), population density, historical flood extent polygons for the region, and infrastructure locations (roads, bridges). The scenario posed a question: "Which areas of the Ust-Kamenogorsk city are at highest risk in the event of a 50-year flood, and what factors contribute to that risk?" Students had to use GIS analysis tools to answer this. The expected approach (which students had to figure out) was to overlay the flood extent for a 50-year event with the land use and population data. In doing so, they would identify, for instance, that certain low-lying residential neighborhoods and agricultural lands fall within the flood zone. They also needed to calculate or estimate the number of people or critical facilities (hospitals and factories) within those zones. Essentially, this assignment combined several skills: spatial overlay analysis, quantitative estimation (how many people affected), and critical thinking to interpret the results. Students then had to write a short analysis report (1-2 pages) summarizing their findings, including maps or tables as supporting evidence. They had to differentiate which factors (e.g., being in a floodplain, having high population) contributed most to risk and explained why those areas were particularly vulnerable. This aligns with Bloom's Analysis level, which involves breaking a problem into parts and understanding their relationships.

By this point, students had some experience with GIS from the application assignment, so the scaffolding was lighter, focusing mainly on conceptual guidance. The assignment prompt included pointed questions to guide the analysis, such as: 'Look at the land cover in flooded areas – is it mostly urban or rural? What does that imply?' and 'Consider the population layer – which flooded districts have the highest population density?'. These questions served as hints on what relationships to examine. Students were given freedom to choose specific analysis tools (e.g., they could use a geoprocessing tool to intersect layers, or they could do visual analysis with the map). To ensure they did not feel completely lost, the teacher held a brief lecture before they started, reviewing possible strategies (reminding them of the existence of a 'Intersect' tool to combine layers and suggesting how to use it and etc.). The expectation was that students would now synthesize the techniques they learned earlier and apply them in a more complex, decision-making context. The scaffolding here was more about coaching: prompting students with the right questions rather than giving solutions. This assignment was a critical step in the scaffold, as it transitioned students from following instructions to independently analyzing and making sense of GIS data. Success on this assignment indicated readiness for the even less structured synthesis task to follow.

The scaffolded group's mean score (≈ 82.9%, SD ≈ 7.8) greatly exceeded the control's (≈ 69.4%, SD ≈ 10.7). This difference (~13.5 points) was significant ($p < 0.001$) with a large effect ($d \approx 1.4$). Despite one low outlier in the scaffolded group, overall Analysis-level performance was much better with scaffolding.

Synthesis Level – Creating an Integrated Flood Management Plan

The fifth assignment was designed for the Synthesis (or "Create") level of Bloom's Taxonomy. At this level, students must combine elements of their knowledge and skills to produce something original. The objective was for students to design a simple flood management plan for a region, integrating GIS analysis with creative problem-solving. In essence, they had to create a comprehensive solution using what they have learned.

This assignment took the form of a mini project. Students were grouped into teams of two or three (to encourage collaboration and idea exchange, as often beneficial in synthesis tasks). Each team was given a new scenario: a town located along a river that is considering various flood mitigation measures. They were provided with relevant data (terrain, river flow rates, etc.) and asked to use GIS to formulate a plan to manage future flood risk. Students' final objective was to produce flood risk maps for Ertys basin in East Kazakhstan. Students were instructed to produce a map layout showing the predicted flood extent, complete with legend and title, and to export the map as an image. As a result, 3 maps were produced: Flood hazard, Population vulnerability and Flood risk for population. Examples of the maps are shown in the Fig. 2.

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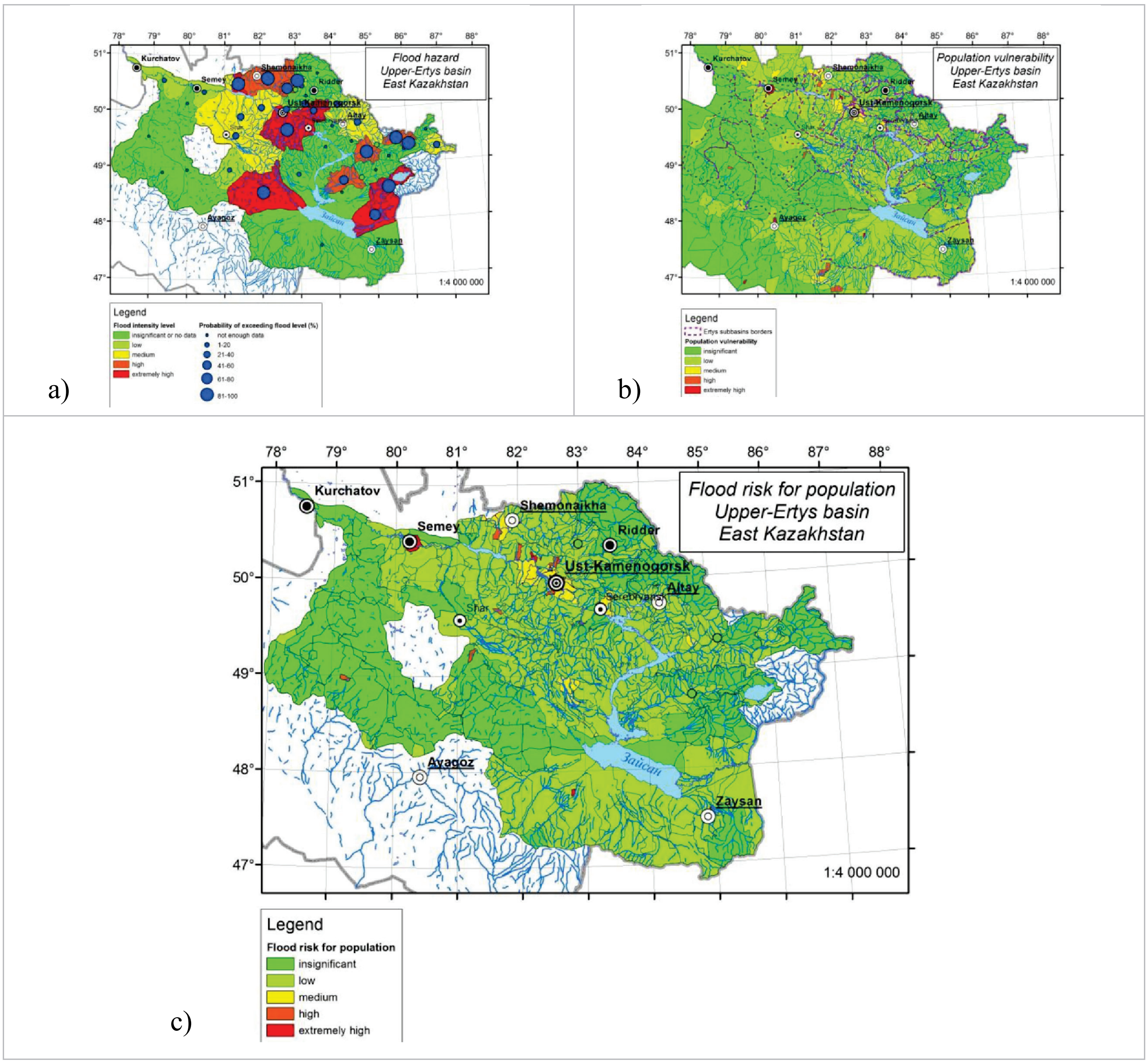

Figure 2. Example set of maps produced by students during Assessment 5 for Ertys river basin in East Kazakhstan: a) Flood Hazard map, b) Population vulnerability map, c) Flood risk for population

Synthesis stage involved multiple steps that the students had to define for themselves. For example, one expected component was that they had to map out areas for potential dam construction or wetland restoration by considering where flooding is most severe (from prior analysis) and what land is available. They also needed to consider evacuation routes or shelter locations, which required overlaying flood maps with road networks and population centers. Essentially, each team had to synthesize data from different sources and come up with a set of recommended actions or strategies, presenting their plan as a report and accompanying maps. The deliverables included: a GIS map highlighting their proposed interventions (e.g., dam locations on the map, zones marked for no development), and a written rationale explaining how their plan would reduce flood impact and why they chose those measures. This assignment was open-ended – there was not a single 'correct' answer, rather the teams were evaluated on how well they justified their plan using evidence from GIS analysis and whether their plan was logically consistent and feasible.

At the synthesis level, scaffolding was minimal and took the form of resources and feedback rather than instructions. Students had full liberty to define their workflow; however, they were provided with certain tools: for instance, they had access to a database of flood management strategies. There also was an organized brainstorming session in class where teams sketched out initial ideas on a whiteboard and got peer and teacher feedback. This helped ensure their approach was on a reasonable track. Each team also had to submit a one-page proposal before fully executing the plan, outlining what they intended to do. The teacher reviewed these proposals and gave each team feedback or suggestions (for example, advising if they overlooked a critical dataset or if their plan seemed too narrow). This form of scaffold – feedback loops – guided them without dictating their final creation. Essentially, the support here was in planning and reflecting, not in carrying out the technical steps, which by now they were expected to manage. The synthesis assignment really put to test the cumulative knowledge and skills gained; students were building something new by drawing on everything from basic map reading to advanced analysis. By completing this project, students demonstrated the ability to not only use GIS tools but also to integrate multiple perspectives (environmental, social, infrastructural) into a coherent flood management solution.

The scaffolded group averaged 87.9% (SD ≈ 5.2) compared to the control group's 75.2% (SD ≈ 6.4). This ~12.7-point gap is statistically significant ($p < 0.001$). The effect size is very large ($d \approx 2.2$), indicating the scaffolded approach had a major impact on Synthesis-level tasks.

Evaluation Level – Critiquing and Presenting Flood Map Results

The sixth and final assignment addressed the Evaluation level. Students were expected to judge and critique information and methods, and to justify decisions. The objective for students was to evaluate the effectiveness of different flood mapping approaches and reflect on the accuracy and limitations of their own work.

This assignment was structured as a reflection and presentation exercise. After the completion of the synthesis project, each team exchanged their flood management plan report with another team. Students had to perform a peer review: each team evaluated another team's plan and wrote a critique assessing its strengths, weaknesses, and viability. They were guided to consider questions like: 'Are the proposed flood mitigation measures supported by the data analysis?', 'What potential challenges or uncertainties might affect the plan?', and 'Which aspects of the plan do you find most effective or innovative, and which would you improve?'. In addition to peer review, each student individually wrote a brief reflection on their own learning throughout the course, essentially evaluating their experience: what techniques they found most useful, which assignment was most challenging, and how well they felt prepared by the scaffolded structure for the final project. Finally, the course concluded with oral presentations where teams presented their flood management plans and defended their decisions. During these presentations, the teacher and students asked evaluative questions ('Why did you choose to focus on dam construction instead of evacuation planning in your strategy?' or 'How would your plan cope with an event more severe than the ones modeled?'). Students had to justify their reasoning and consider alternative viewpoints, exhibiting evaluation-level thinking.

By the evaluation stage, direct scaffolding in the form of guidance was not necessary; instead, the support was in the structured format of the peer review and guided questions, which ensured students had a clear task in their evaluation. The teacher provided a peer review rubric to focus student critiques on relevant aspects (data use, feasibility, creativity, etc.). This rubric acted as a scaffold to the evaluation process, standardizing the criteria for judgment so that even inexperienced reviewers could provide constructive feedback. For the self-reflection, prompts were given ('What would you do differently in your analysis if you had more time or data?', 'Which assignment taught you the most, and why?') to spark thoughtful evaluation of the entire learning process. During presentations, the teacher moderated the Q&A session to push deeper inquiry where needed, but by and large, students took the lead in evaluating and

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discussing each plan. This final assignment completed the scaffolded sequence by encouraging students to step back and critically assess both their peers' work and their own. In doing so, they demonstrated the highest level of cognitive engagement – making informed judgments – and thereby fulfilled the full spectrum of Bloom's Taxonomy in the course's assignments.

The scaffolded group's mean (≈ 88.9%, SD ≈ 3.4) far surpassed the control's (≈ 69.9%, SD ≈ 10.8). This ~19-point difference is highly significant ($p < 0.001$) and corresponds to a very large effect (Cohen's d ≈ 2.3). In this final, higher-order Evaluation task, the scaffolded students performed dramatically better than the control group.

Each of the listed assignments was built upon the previous ones. For instance, the knowledge of terms from Assignment 1 was used in the comprehension explanations of Assignment 2. The mapping skills practiced in the application of Assignment 3 were needed to conduct the analysis in Assignment 4. The insights from analysis (Assignment 4) fed directly into the synthesis project (Assignment 5) where students had to use those insights to design solutions. Finally, the evaluation in Assignment 6 required understanding the entire process and outcomes, bringing the learning cycle to completion. This intentional design ensured continuity and cumulative learning – a hallmark of the scaffolding approach in education [22].

By gradually increasing the complexity and by making each task a prerequisite for the next, students were less likely to feel overwhelmed at any single stage, yet by the end they had engaged in very sophisticated GIS problem-solving.

Discussion

The analysis of student performance across the assignments showed a clear positive trajectory, suggesting that the scaffolded, Bloom-aligned design of the course was effective in building competence. In fact, compared to a non-scaffolded control group, the scaffolded cohort achieved higher average scores at each level of Bloom's Taxonomy (see Fig. 3). Course results for each Assignment are shown in Fig. 4.

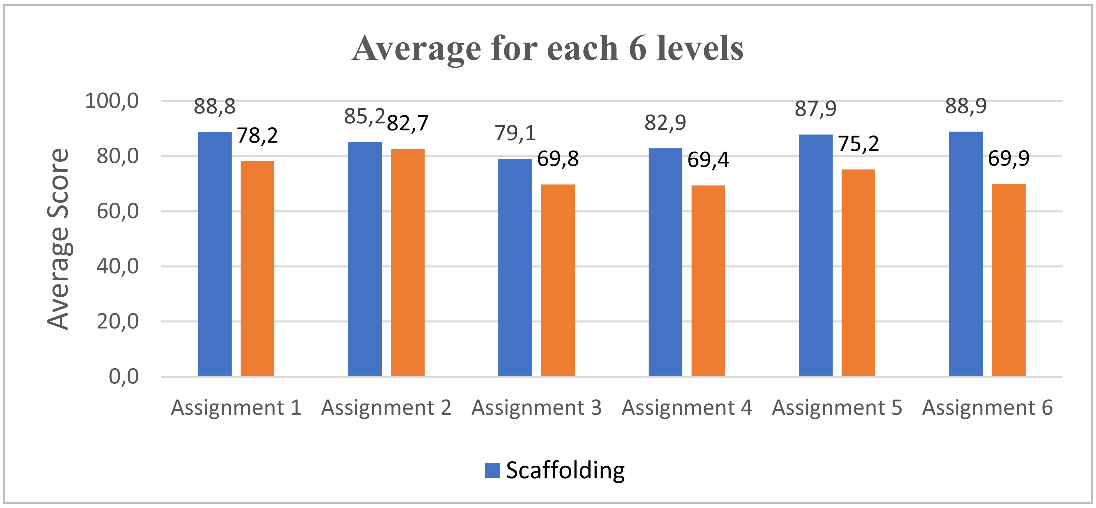

Figure 3. Scaffolding approach average results comparison with control group

The class average on the Knowledge-level assignment (Assignment 1) was high (around 88,8%), as expected for a recall-based task with full support. At the Comprehension level (Assignment 2), students showed similar results (around 85,2%), though slightly lower due to more difficult tasks. By the Application assignment (Assignment 3), which was even more challenging, the average score dropped to about 79,1%, with some students encountering difficulties in the independent use of ArcGIS and QGIS. However, by the Analysis assignment

(Assignment 4), the average rebounded to roughly 82,9%, and for the Synthesis project (Assignment 5) it reached 87,9%. By the final Evaluation activities (Assignment 6), virtually all students successfully completed the peer review and presentation with satisfactory evaluations (around 88,9% average score). Assignment 6 tasks were graded more on the quality of critique and reflection, and most students met the criteria.

Notably, the scaffolded class's scores were consistently higher than those of a comparable control group that did not use the scaffolded approach (Fig. 3). This performance gap was especially pronounced on the higher-order assignments. For instance, in the final Evaluation-level task (Assignment 6), the scaffolded cohort averaged about 88,9% versus only 69,9% in the control group – nearly a 19-point difference. Similarly, at the Analysis level (Assignment 4) the scaffolded group scored around 82,9% compared to 69,4%, and in the Synthesis project (Assignment 5) it achieved about 87,9% versus 75,2%. Even at the lower cognitive levels, the scaffolded section held an advantage: on the Knowledge-level assignment (Assignment 1) it achieved 88,8% versus 78,2%, and at the Comprehension level (Assignment 2) 85,2% versus 82,7%. These results confirm that the scaffolded approach led to higher performance overall (approximately 85,5% class average versus 74,2% in the control) and provided the greatest boost on the more complex, higher-order tasks.

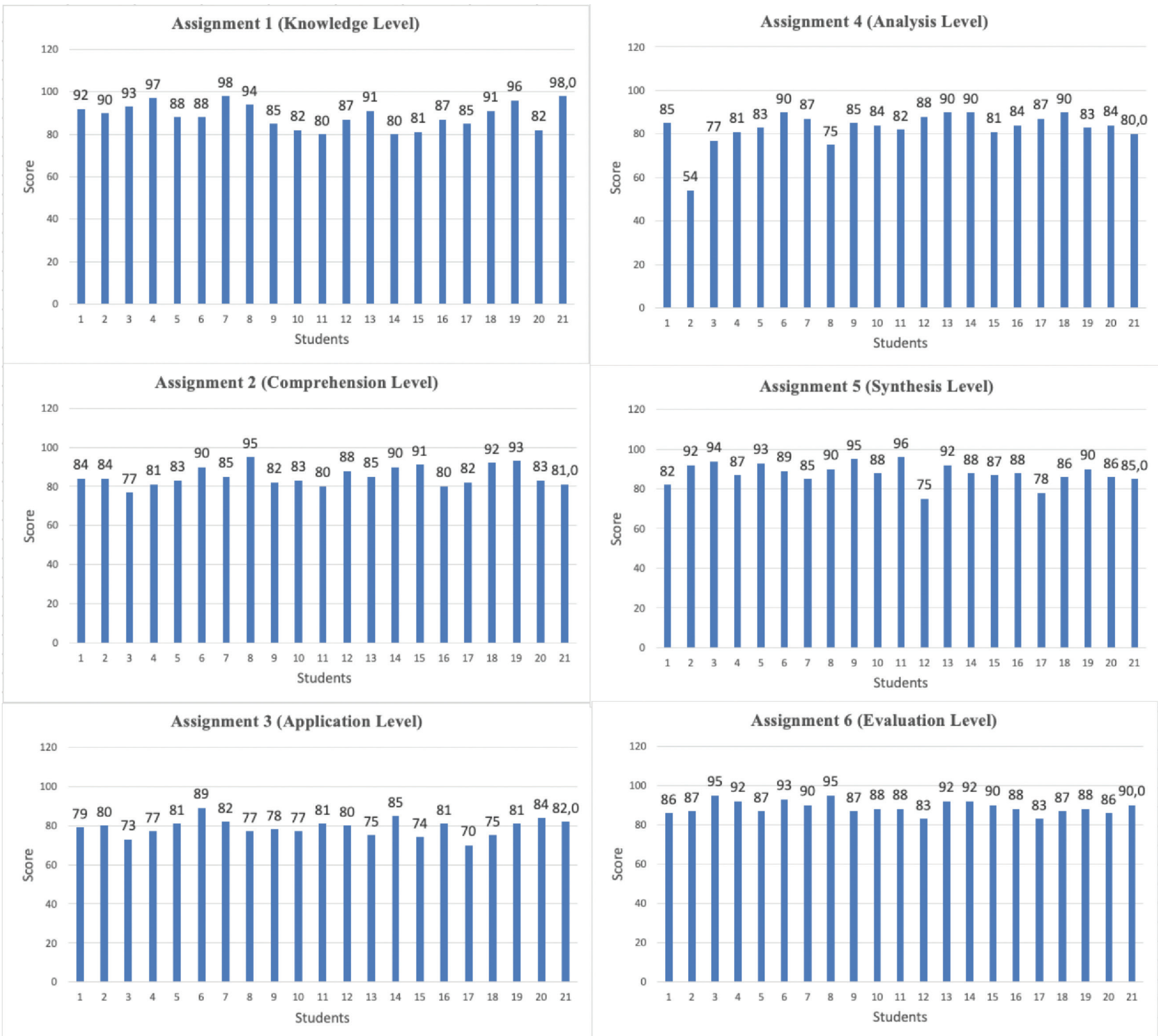

Figure 4. Students' final scores distributed by different levels of Bloom's Taxonomy

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Importantly, improvement was observed not just in the numerical averages but also in the depth of the work produced by students. For example, the quality of answers in the Comprehension assignment improved for some students compared to the Knowledge assignment, showing greater explanatory detail. Similarly, the maps produced in the Synthesis project were significantly more sophisticated than those in the Application exercise. This aligns with the expected outcome of a scaffolded approach: as students gained practice and confidence in early tasks, they performed better on later, more difficult tasks [8].

We also noticed that the number of students needing significant help dropped over time – during Assignment 1 and 2, many asked questions constantly, whereas by Assignment 5, most teams worked independently, consulting the teacher only for confirmation of ideas. The progression in scores and autonomy indicates that the students were internalizing the skills and knowledge incrementally. These findings are consistent with other research that reported improved student competence and skill mastery when using a progressive, scaffolded model in GIS education [16, 21].

For instance, the competence gains we observed mirror those in the portfolio model [16], where students showed enhanced GIS skills and motivation after working through inquiry-based tasks structured by Bloom's levels. To further quantify learning gains, we compared pre-course and post-course assessments. A pre-course quiz administered in the first week had an average score of 60% (students largely guessing on unfamiliar content). A similar quiz at course end saw an average of 85%, demonstrating significant knowledge acquisition. On the final exam's analytical questions (which required reasoning about a new flood scenario), students performed markedly well – approximately 86% of the class provided correct or well-justified answers, indicating that higher-order thinking skills had been developed. In fact, several students tackled the exam's synthesis question (designing a brief flood response plan for an unseen scenario) with creativity and confidence that arguably came from having practiced such tasks in the assignments.

These quantitative outcomes reinforce that the scaffolding not only helped students get through assignments, but led to genuine learning that they could transfer to new problems. This reflects [20] findings that scaffolded learning exercises led to skill transfer to independent projects.

Qualitative data from surveys and discussions provided insight into student engagement and their perspective on the scaffolding approach. Overall, engagement was high throughout the course. Many students commented that the flood mapping context was motivating because it felt like solving a real problem connected with their home region, not just a textbook exercise. The step-by-step increase in challenge kept them interested: a common sentiment was that each assignment felt like a "level up" in a game, which was rewarding upon completion. In the survey, 86% of students agreed or strongly agreed that the progression of assignments helped them learn effectively. They reported that early assignments gave them the confidence to tackle later ones. One student wrote, "At first I was nervous about using GIS, but after the first two assignments I felt prepared to do the projects on my own." Another noted, "The way each assignment built on the last meant I never felt lost – I always had some idea of how to start the next task." This kind of feedback indicates that the scaffolding reduced the intimidation factor of a complex subject, echoing the notion that scaffolding builds student confidence step by step [8].

Students also enjoyed the synthesis project; working in teams on a real-world problem was mentioned as a highlight, suggesting that by the time they reached that stage, they were sufficiently engaged and skilled to appreciate a challenging project.

However, feedback also revealed some challenges and varied experiences. A majority found the approach beneficial, but a few students did not perceive as much benefit. Approximately 14% of students (often those with prior GIS experience) felt that the initial assignments were too basic or slow. One advanced student said, "I already knew the basics, so the first assignments felt like repetition. I was impatient to get to the interesting stuff." This points to a general challenge in scaffolding: prior knowledge differences. In our case, we mitigated this by offering optional extension tasks for those who finished early (for example, a bonus challenge in Assignment 1 for advanced students to find additional terms), but some still felt under-challenged initially. On the other end of the spectrum, a couple of students struggled even with scaffolding – they needed repeated help even by the analysis stage. Those students commented that while they appreciated the structured approach, they still found ArcGIS difficult and would have liked even more guided practice before the project. This highlights that scaffolding doesn't eliminate all difficulties; individual learning curves vary. These observations align with [16] finding where most students found the learning experience challenging (though some students did not).

It's worth noting that even students who struggled did manage to complete the work with acceptable results, but their confidence was lower. This suggests a need for possibly even more differentiated scaffolding – perhaps offering remedial help or extra practice for those who need it, while letting advanced learners skip ahead.

Another challenge was the time and effort required to implement this approach. From the teacher's perspective, creating six interlinked assignments with appropriate supports was labour-intensive. It required careful planning to ensure consistency (for example, that the output of Assignment 3 genuinely helped in Assignment 4, etc.). Additionally, providing detailed feedback at each stage (especially for the synthesis proposals and final reflections) took significant grading time. This is an important consideration for educators: scaffolding can improve learning outcomes, but it demands a higher upfront investment in assignment design and continuous support. Nonetheless, the payoff was apparent in student success and satisfaction.

Despite the challenges, the overall effectiveness of the approach is evidenced by both the performance outcomes and the student feedback. Students not only learned GIS flood mapping skills, they could also integrate and apply them in a meaningful context by course end. The scaffolded design appears to have kept students in what Vygotsky's theory of cognitive development would call the "Zone of Proximal Development" – tasks were just beyond their independent ability but achievable with support, until they eventually could do those tasks alone. The high level of engagement and the quality of final projects suggest that students were indeed operating at a high cognitive level by the end, which is a primary goal of higher education learning. One telling sign of success was that several students voluntarily went beyond the requirements in their final projects (running advanced spatial analyses we hadn't explicitly taught). This kind of initiative indicates that the scaffolded steps not only taught specific skills but also empowered students to explore further – they had developed enough confidence and interest to exceed the basic expectations.

Comparing our results to those in the literature, we see strong parallels. Findings that students showed improved performance and confidence confirm patterns found in scaffolded GIS learning studies [16], [20]. Additionally, the increased motivation we observed is in line with [16]'s observation that an inquiry-based, Bloom-structured approach developed student motivation to learn about GIS.

On the other side, the issues we encountered (advanced students feeling initial work was too easy, some students needing more support) are also echoed in the literature. In [16] the need for clearly defined outcomes and rubrics for scaffolded tasks was emphasized, which we implemented via detailed rubrics, so students knew exactly what was expected at each stage. In [16] the authors also note that effective scaffolding requires careful design, which our experience confirms. We found that a transparent structure helped students see the value in each

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step, even if it felt easy. In the focus group, one initially sceptical student conceded, "I thought the first tasks were too simple, but later I realized I would have been lost in the project if I hadn't done them." This comment underlines how scaffolding can sometimes be under-appreciated by learners until they tackle complex tasks and recognize the foundation that was laid.

An interesting challenge in evaluating such an approach is isolating the effects of scaffolding and Bloom's structured progression. There is no concurrent control group in this study, but the outcomes can be compared to a prior offering of a similar course that used more traditional (non-scaffolded) teaching approach. The teacher noted that in that earlier course, student outcomes were not as strong: for example, the final projects were of lower quality and more uneven, and students seemed more anxious. Quantitatively, as shown by the averaged results in Fig. 3, the scaffolded cohort outperformed that previous class on equivalent assignments across the board. While this was not a randomized experiment, this contrast suggests that the scaffolded, Bloom-aligned design made a significant difference. Future studies could formalize such comparisons.

One of the key findings that emerged is the critical role of teacher facilitation in scaffolding. While the assignments were doing a lot of the structural work, the presence of the teacher as a guide at crucial moments was important. This approach confirms that technology and written guides alone are not enough; the educator's interventions (hints, feedback, encouragement) were vital, especially for students who struggled or for teams brainstorming complex solutions. This supports the notion from the literature that a teacher-centered approach is also very important even alongside digital or student-centered strategies [16]. It is recommended that educators planning to implement scaffolded assignments should be prepared to remain actively engaged with the students. Scaffolding is not a hands-off teaching method; it is quite hands-on at first and gradually transitions to hands-off as students gain independence. The art for the teacher is knowing when to step in and when to step back. In this case study, occasional mini lectures had to be provided when common misunderstandings were noticed (for example, during the analysis assignment some students misinterpreted how to calculate affected population, so we paused to clarify the method for all). These just-in-time teachings were not in the original plan but became part of the scaffold as needed. This flexibility is an important aspect of successfully scaffolding a course.

In summary, the results of this study demonstrate that using Bloom's Taxonomy as a blueprint for assignment difficulty and employing scaffolding techniques can significantly enhance student learning in a GIS-based flood mapping course. Students not only performed better but were also highly engaged and developed higher-order thinking skills by the end of the course. The approach was effective in guiding students from basic knowledge to complex evaluation in a systematic way. Challenges such as catering to varying skill levels and the increased effort required to design such a course can be managed with careful planning and ongoing teacher support. The findings here contribute to the growing evidence that scaffolded learning experiences in geospatial education not only help students achieve immediate learning outcomes but also prepare them to apply their knowledge in real-world contexts – a key aim of education in the sciences and applied fields.

Conclusion

This study set out to examine how structured, scaffolded assignments based on Bloom's Taxonomy can improve the teaching and learning of GIS, using flood mapping as a focused application. The development and implementation of a sequence of assignments - from foundational knowledge drills to an open-ended flood management project - showcased a practical way to gradually elevate students to higher-order thinking and independent problem-solving. The results support several conclusions.

First, integrating Bloom's Taxonomy into assignment design provided a clear roadmap for both instructor and students. It ensured that lower-level cognitive skills were mastered early and that assignments explicitly targeted increasingly advanced skills. Students ended up performing analysis, synthesis, and evaluation tasks with confidence, a progression that might not have happened without the deliberate build-up.

Second, the use of instructional scaffolding was validated as an effective method in this context. The gradual release of responsibility – from guided instruction in early exercises to autonomy in the final project – correlated with improved student competence and motivation, echoing pedagogical research recommendations [20], [21], [22]. The scaffolded approach kept students within reach of the next challenge without causing discouragement that can occur when tasks are too difficult too soon.

Several practical recommendations for educators emerge from this work. When designing technical courses or any complex skill curriculum, it is beneficial to break down the learning objectives into the tiers of Bloom's Taxonomy and create assignments that correspond to each tier. This not only clarifies to students the purpose of each assignment but also helps teacher ensure that all cognitive levels are addressed. In implementing scaffolded assignments, teacher should provide support in the early stages – such as examples, step-by-step guides, and feedback – and plan to reduce this support as students become more capable. It is also recommended to communicate the structure to students, so they understand that each task is preparing them for the next. This can increase student buy-in, especially for those who might otherwise skip 'easy' steps. Another recommendation is to use clearly defined learning outcomes and rubrics for each assignment [16]. It was found that having specific criteria for success (e.g., what constitutes a good map or a good analysis) helped students focus on the right things and allowed them to self-evaluate their work against those criteria. A well-defined rubric acts as a scaffold, guiding students on how to achieve the goals of an assignment. Additionally, maintaining flexibility is important: teachers should be ready to adjust the pace or provide extra scaffolding if the class seems to need it, or conversely, to offer enrichment for advanced learners to keep them challenged. In current case, small tweaks like bonus tasks and optional challenges helped accommodate different skill levels.

For future research, this study opens several directions. One area is to formally measure the impact of scaffolding by comparing sections of a course with and without scaffolded assignment design, to quantify differences in learning outcomes and student satisfaction. Another possible direction is to explore scaffolding in an online GIS course setting, where teacher presence is limited to virtual interactions. With the rise of online learning, understanding how to effectively scaffold in that environment is valuable. It would also be fruitful to investigate the long-term retention of skills gained through this method. Furthermore, applying this framework to other topics (e.g., climate change mapping, urban planning GIS, or even outside GIS to other technical disciplines) could test its generalizability. Each discipline might have its nuances, but the core principle of building up from basics to complexity with guided support should be widely applicable.

In conclusion, the development of GIS assignments for flood mapping using Bloom's Taxonomy and scaffolding proved to be a successful strategy for enhancing student learning. Students became actively engaged in the learning process, moving from simple recall of concepts to evaluating complex scenarios in a matter of weeks. The scaffolded approach not only imparted technical GIS skills but also improved higher-order thinking, problem-solving abilities, and confidence – outcomes that are highly desirable in education. By carefully structuring learning experiences and supporting students at each step, educators can create an enriching learning journey that empowers students to tackle challenging real-world problems. This approach aligns with the broader educational goal of not just teaching content but developing learners who are capable of critical thinking and independent learning.

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