

# Advancing Outcome-Based Education Through Student Engagement and Computational Innovation: A Case Study in Number Theory and Combinatorics

Hui Li\*, Shining Yu, Yichi Zhang and Chenlong Liu

*Department of Computer Science and Technology, Beijing University of Chemical Technology, Beijing 100029, China.*

**Abstract:** We present a comprehensive case study of implementing Outcome-Based Education (OBE) in the "Number Theory and Combinatorics" course for computer science majors. By systematically aligning curriculum design, assessment methods, and teaching strategies with clearly defined learning outcomes, we show the case how OBE principles can be effectively operationalized in STEM education. The reform integrates advanced computational technologies—including self-developed knowledge graphs for conceptual structuring and data-driven visualization tools for performance analytics. Through multi-dimensional assessment and active learning initiatives, students are transformed from passive recipients into active co-creators of the educational process.

**Keywords:** Outcome-based education, Curriculum design, Knowledge graph, Mathematical statistics.

## 1. INTRODUCTION

Outcome-Based Education (OBE), originally proposed by Spady in 1988 (Spady, 1988), is a student-centered instructional framework that begins with clearly defined learning outcomes and aligns curriculum design, teaching methods, and assessment strategies accordingly. Its core philosophy is that every component of the education system should serve the ultimate goal of helping all students achieve specific, measurable competencies. By shifting the focus from what is taught to what is learned, OBE supports more targeted teaching and enables institutions to track educational effectiveness more precisely. Despite its advantages, OBE has been critiqued for potentially narrowing learning by emphasizing predetermined goals, which may limit students' creativity and reduce opportunities for exploratory learning. Furthermore, overreliance on outcome metrics may fail to fully reflect students' holistic development. Nevertheless, these drawbacks can be addressed through thoughtful pedagogical strategies that blend structure with flexibility, allowing educators to meet OBE objectives while still fostering innovation and individual growth (Asbari & Novitasari, 2024).

In recent years, OBE has become a foundational element in educational reform worldwide and has been actively integrated into China's higher education policies and practices (Wang & Liu, 2024). The successful implementation of OBE demands a systemic transformation that includes setting explicit learning outcomes, revising curricula, redesigning

assessments, adopting learner-centered instructional approaches, and establishing mechanisms for continuous feedback and improvement (Mufanti *et al.*, 2024). Collaborative planning among faculty and institutional support are also key to sustaining these reforms.

Integrating computer technology with OBE further amplifies its impact by offering scalable and adaptive learning tools. Digital platforms facilitate the development of online tutorials, multimedia instruction, and interactive assessments that empower students to take ownership of their learning (Mouratidis & Papagiannakis, 2021). Digital platforms contribute to instructional efficiency by assisting educators in content creation, curriculum design, and formative assessment. Teachers can leverage these models to draft lesson plans, summarize large volumes of material, or develop rubrics and quizzes aligned with learning outcomes. This not only reduces workload but also allows educators to focus more on student-centered activities and feedback. As digital platforms continue to evolve, their integration into teaching practices holds promise for fostering more inclusive, efficient, and outcome-oriented education systems (Makda, 2025).

Modern educational technologies such as graph visualization tools and algorithm animation systems play a crucial role in making abstract computing concepts more accessible (Samala *et al.*, 2024). By enabling students to observe system behavior dynamically and in real time, these tools foster interactive exploration and deepen conceptual understanding through visual reinforcement. When paired with programming assignments—typically implemented in languages like Python—students gain

\*Address correspondence to this author at the Department of Computer Science and Technology, Beijing University of Chemical Technology, Beijing 100029, China; E-mail: ray@mail.buct.edu.cn

hands-on experience that bridges theory and practice, enhancing their problem-solving abilities in real-world application (Ahmad *et al.*, 2024).

Simultaneously, the widespread integration of digital assessment platforms has revolutionized how educators monitor and support student learning (Bitar & Davidovich, 2024). Features such as online quizzes, automated code evaluation, and real-time learning analytics streamline feedback and allow for continuous performance tracking. Recent innovations in AI-driven educational tools, particularly transformer-based models, have further advanced the accuracy of automated assessments. These intelligent systems can evaluate code quality, diagnose common errors, and provide constructive feedback, helping students improve both technical skills and coding style (Messer *et al.*, 2023).

In parallel, Large Language Models (LLMs) like GPT-based systems are reshaping the learning experience by delivering personalized, on-demand educational support. These models can generate tailored explanations, provide immediate feedback, and simulate one-on-one tutoring interactions, accommodating a wide range of learning preferences and proficiency levels. Some scholars argue that LLMs are prone to factual inaccuracies, known as "hallucinations," where the model produces plausible-sounding but incorrect or fabricated information (Ji *et al.*, 2023). However, by assisting with concept clarification and generating customized practice materials, LLMs significantly boost student engagement and comprehension, particularly in self-paced or hybrid learning environments (Shahzad *et al.*, 2025).

"Number Theory" investigates the fundamental properties of integers and serves as a crucial mathematical foundation, while "Combinatorics" focuses on the existence, construction, enumeration, and optimization of discrete object sets under specific conditions. "Number Theory" is directly applicable to information security and cryptography, and "Combinatorics" is essential for computer algorithm analysis, complexity theory, and many other fields beyond computer science. Through classroom instruction, students develop strong analytical and problem-solving skills, learn to model and analyze problems in computer science and related disciplines, and build a solid foundation for future engineering practice and scientific research (Broy *et al.*, 2024).

To further bridge theory and practice, we have integrated industry case studies into the curriculum that demonstrate how number theory and combinatorics underpin real-world applications. For example, number

theory forms the mathematical backbone of modern cryptographic systems such as RSA and elliptic curve cryptography, which are widely used to secure digital communications and financial transactions (Li, 2020). Combinatorial optimization and algorithm design are central to solving large-scale scheduling, logistics, and network problems in technology companies and the finance sector (Yang *et al.*, 2022). Students are encouraged to participate in hands-on projects that simulate the development of cryptographic protocols or the design of efficient algorithms for real-world datasets. Recent analyses indicate that graduates with strong backgrounds in these areas are highly sought after in the global job market, with employers valuing their ability to translate mathematical concepts into innovative technological solutions (Forum, 2023).

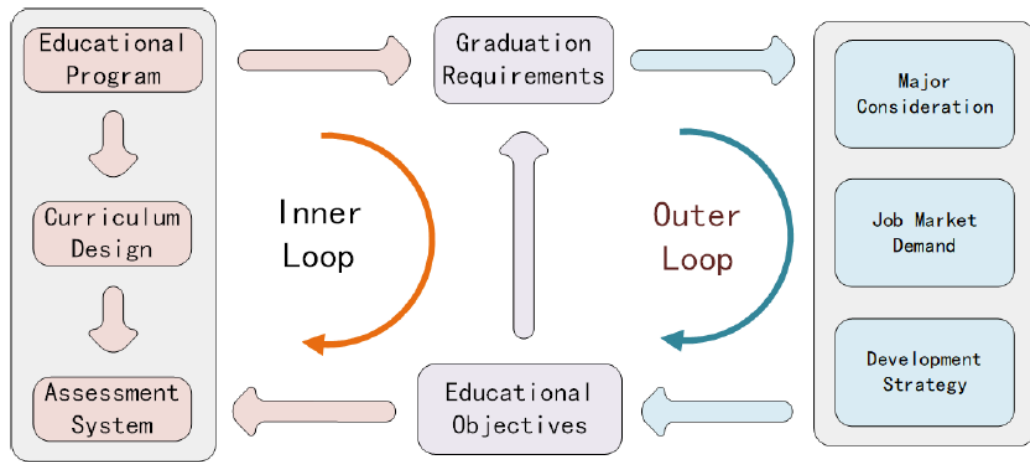
In this paper, we present a case study of the "Number Theory and Combinatorics" course offered at the authors' institution, a famous university in China, to illustrate its implementation within the OBE framework. We examine how the integration of computer technology enhances multiple dimensions of OBE teaching through concrete, practice-based examples. Our findings suggest that incorporating technological tools into the instruction of "Number Theory and Combinatorics" not only improves the efficiency of OBE delivery but also enhances both the quantity and quality of student learning outcomes, underscoring the transformative potential of digital technologies in education. Notably, all the tools and systems discussed in this study were independently developed and implemented by computer science students. Through their engagement in OBE-aligned programming projects, these students have demonstrated strong industry readiness and competitiveness. A key contribution of this work lies in its demonstration of a shift from students as passive recipients of education to active participants and co-creators.

The remainder of this paper is organized as follows: Section 2 introduces the requirements and plans for OBE reform; Section 3 discusses the application of computer technology and student engagement in the teaching process; Section 4 introduces the practice of continuous improvement and outlines future plans for leveraging computer technology in OBE teaching; and Section 5 concludes the paper.

## 2. OBE REQUIREMENTS AND REFORM PLANS

### 2.1. OBE Framework

Figure 1 illustrates the overall framework for implementing OBE. To ensure the effectiveness of OBE, teaching outcomes are regularly evaluated and revised with input from industry experts, and



**Figure 1:** Outcome-based teaching framework (revised, March 5th, 2025).

graduation requirements are established based on these defined outcomes. These requirements encompass a broad range of competencies, including engineering knowledge, problem analysis, design skills, research abilities, and more. The OBE reform thus addresses the needs of society, industry, higher education institutions, and individual student development.

Within the OBE framework, the system operates through two interconnected cycles: an internal cycle, which focuses on internal actions and feedback, and an external cycle, which incorporates feedback from outside the university. All faculty members convene every four years to revise the framework, with the most recent update occurring in 2025.

To fulfill the requirements of OBE in the “Number Theory and Combinatorics” course, we have implemented several targeted measures. First, we established clearly defined learning outcomes, outlining the specific knowledge, skills, and attitudes students are expected to develop by the end of the course. These include the ability to analyze algorithms from the perspectives of number theory and combinatorics, strengthened logical reasoning skills, and the capacity to apply mathematical principles to computer science and related disciplines.

To evaluate teaching effectiveness, we designed multiple questionnaires (see Table 1 for an example) and conducted comprehensive statistical analyses of student performance beyond standard results. These analyses provide insights into individual learning progress and support data-driven instructional adjustments. We also maintain a continuous evaluation cycle for the curriculum reform, using regular student feedback to assess the alignment with OBE goals and to refine teaching strategies accordingly.

Recent research in educational psychology highlights the critical role of intrinsic motivation in fostering deep and sustained engagement with STEM subjects. According to Self-Determination Theory (SDT) proposed by Deci and Ryan, active learning environments that support students’ autonomy, competence, and relatedness can significantly enhance intrinsic motivation (Deci & Ryan, 2000). When students are intrinsically motivated, they are more likely to participate actively, persist in the face of challenges, and achieve higher levels of understanding. Empirical studies have shown that students involved in active learning and who report higher intrinsic motivation tend to perform better in mathematics and computer science courses (Córdova-Esparza *et al.*, 2024). Thus, integrating active learning strategies not only deepens conceptual understanding but also cultivates the psychological conditions necessary for long-term academic success in STEM disciplines. We have incorporated active learning strategies to promote deeper engagement with course content. Students participate in problem-solving, critical thinking exercises, and collaborative tasks that reflect practical applications of number theory and combinatorics. For instance, Python programming is used to explore and verify properties such as operation tables in algebraic number fields. Currently, one-third of after-class assignments are programming tasks, which require students to submit program source code and screenshots of runtime results. These programming assignments are integrated throughout the entire teaching process.

To further support student learning, we offer a range of supplementary resources and guidance. These include question banks, exercise sets, study notes, online tutorials, curated educational websites, and interactive learning platforms. Such resources aim to enhance students’ understanding of the material and foster communication between students and instructors,

**Table 1: Evaluation Criteria and Corresponding Scores (Revised, March 5th, 2025)**

Evaluation Criteria	Target Score	Actual Score
Observes teaching discipline, energetic, serious, rigorous, well-presented	20	17
Clear, concise, rigorous lecture language, appropriate volume and speed, expressive and engaging	20	16
Substantial content, clear logic, emphasis on key points, addresses difficulties	15	12
Effective use of various teaching media, standardized blackboard writing	15	13
Inspires, guides, and interacts with students, stimulates initiative, enthusiasm, and curiosity	15	12
Content relates theory to practice, incorporates domestic and international research, presents cutting-edge knowledge	15	11

creating a more supportive and collaborative learning environment.

## 2.2. Learning Performance Assessment

Assessing learning performance is a fundamental component of OBE, as it enables the systematic tracking of student progress and comprehension.

In developed countries such as Germany and Finland, continuous assessment models often emphasize formative feedback, criterion-referenced grading, and student-centered learning (Ortega-Alvarez *et al.*, 2025), which contrast with the more exam-oriented systems prevalent in China and many Southeast Asian countries (Deng, 2024). For instance, European universities frequently implement ongoing coursework, project-based evaluation, and oral examinations in mathematics and computer science courses, fostering deeper engagement and skill development. In contrast, assessment in some Asian contexts remains more summative and high-stakes, though recent reforms are increasingly incorporating formative elements and diversified evaluation methods. Comparative studies suggest that the integration of continuous assessment in STEM not only supports student learning but also aligns with global trends toward outcome-based education and lifelong learning (Roehrig *et al.*, 2021). In the "Number Theory and Combinatorics" course, the integration of student-developed web-based statistical visualization tools enriches the learning performance assessment process. This not only empowers students to gain deeper insights into their individual learning trajectories but also equips instructors to make timely, data-driven adjustments and deliver targeted support.

Student grades are composed of three primary components: continuous assessment, team project, and examination scores. Continuous assessment mainly encompasses homework and classroom participation. Homework is graded based on timely completion, while participation is evaluated through attendance, responsiveness in class discussions, and

overall engagement. This component accounts for 25% of the final grade and reflects the student's ongoing involvement throughout the course. Under the blended learning model, these metrics are further enriched by data from the online learning platform.

To better align with OBE principles, we have diversified our assessment methods by incorporating projects, homework, and test, etc. This comprehensive evaluation framework allows for the measurement of a broader range of student competencies. Students are expected to engage actively, prepare thoroughly, complete projects independently, and submit reports punctually. Team project, is assessed through a detailed rubric that takes into account both the team's collective output and each member's individual contribution. The team project assessments are conducted throughout the course: those embedded within project evaluations and standalone regular programming tasks. These assessments challenge students to solve problems within a specified timeframe, thereby testing their ability to apply programming knowledge effectively under time constraints.

Each academic year, we invite at least five industry professionals to the university to evaluate the performance of recent graduates and provide external insights into the effectiveness of our teaching practices. We also collect feedback from a minimum of five alumni currently employed in industry, through online surveys and interviews, to solicit suggestions for optimizing the "Number Theory and Combinatorics" course. These insights are instrumental in refining both our student performance assessments and curriculum design, ensuring the course remains relevant and aligned with industry expectations. Table 2 shows the student assessment items revised in 2025.

In addition to annual consultations, we are actively developing long-term partnerships with leading technology companies. These collaborations are designed to ensure that our curriculum remains closely aligned with evolving industry standards and employer expectations. Through joint curriculum development,

guest lectures, and industry-sponsored projects, students gain exposure to real-world challenges and acquire practical skills that are highly valued in the technology sector. For example, students participate in hands-on workshops and internships facilitated by these companies, which provide invaluable experience in applying theoretical knowledge to authentic industry problems. Empirical studies have shown that such industry-university partnerships significantly enhance students' employability, practical competencies, and readiness for STEM careers (Taş, 2024). Data from our online surveys indicate that students involved in industry-collaborative programs report higher confidence in their technical abilities and demonstrate improved job placement rates upon graduation.

**Table 2: Student Assessment (Compared to before the Reform, the Weight of the Final Exam Decreased from 70% to 20%, Revised, March 5th, 2025)**

Item	Percentage (%)
Class Attendance	10
Class Participation	10
Homework	20
In-class Quiz	10
Team Project	10
Midterm Exam	20
Final Exam	20

### 3. APPLICATION OF NEW TECHNOLOGY AND STUDENT ENGAGEMENT

#### 3.1. Application of Machine Learning and Computer Technology

The integration of computer technology into the "Number Theory and Combinatorics" course has enabled students to engage in a wide range of interactive learning activities, such as questions and answers, online discussions, and quizzes. These interactive experiences not only stimulate students' interest in learning but also significantly enhance their understanding and ability to apply key concepts. Furthermore, computer technology facilitates the delivery of personalized learning resources and teaching methods tailored to individual student needs, allowing each learner to progress at their own pace and explore areas of personal interest.

Machine learning algorithms are increasingly central to adaptive learning assessments, enabling systems to dynamically tailor educational content to individual student needs and learning styles. Techniques such as clustering, classification, and

sequence modeling (e.g., BiLSTM-CRF) can be used to analyze student performance data and recommend personalized learning paths (Zhu, 2024). AI-driven tutoring systems in mathematics and computer science education can detect students' difficulties in real time and provide targeted practice or feedback, thereby improving learning outcomes (Ouyang *et al.*, 2023). Our studies have demonstrated that such intelligent systems not only enhance engagement but also foster deeper conceptual understanding and self-regulated learning in STEM disciplines. For example, adaptive platforms leverage continuous data-driven evaluation to track progress and adjust instructional materials, ensuring that each learner receives support matched to their evolving proficiency. The students admitted in 2023 have higher admission scores than those in 2022. From the AI platform, we observed that they performed better on their first few quizzes. Therefore, we adjusted by increasing the difficulty of the course content, aiming to help students develop a deeper understanding of the subject.

A key innovation in our teaching reform is the integration of knowledge graphs into both courseware and online supplementary materials. Knowledge graphs provide a structured representation of entities (such as terms in "Number Theory and Combinatorics") and their relationships (Cao *et al.*, 2024). In the context of OBE, knowledge graphs offer students organized and systematic learning resources. In practice, we modeled the key knowledge points, concepts, and their interrelationships within the course to construct a comprehensive knowledge graph (see Figure 2). This graph is closely integrated with the online learning system and lecture notes. Knowledge graphs facilitate a deeper understanding of the overall structure of the knowledge system.

We developed a dedicated knowledge graph for the course and converted the term in the online learning system into enhanced visualization. For example, as shown in Figure 3, we highlight key terms as nodes within the knowledge graph, making the relationships between concepts more explicit and accessible. They help both instructors and students to organize and visualize related concepts and their interconnections more effectively.

In addition to knowledge graph integration, we have developed custom software tools to implement both class-level and individual-level learning outcome assessment systems. These tools enable the collection, analysis, and visualization of student performance data, supporting data-driven decision-making for both teaching and learning. By leveraging these technologies, we are able to provide timely feedback, identify learning trends, and offer targeted support to

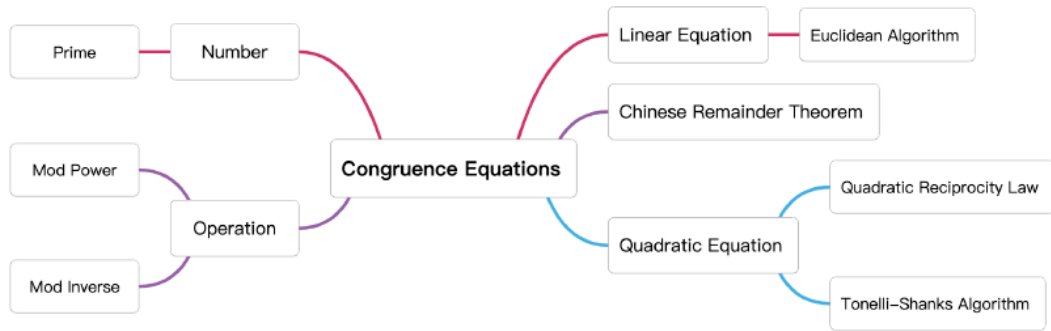


Figure 2: Knowledge graph of Number Theory and Combinatorics.

The **Tonelli-Shanks algorithm** is used to solve congruence equations of the form  $x^2 \equiv n \pmod{p}$ , where  $n$  is a **quadratic residue** modulo  $p$ , and  $p$  is an odd **prime**.

Input:

- $p$ : an odd **prime**;
- $n$ : a **quadratic residue** modulo  $p$ , satisfying the **Legendre symbol**  $\left(\frac{n}{p}\right) = 1$ .

Output: |

- $R$ : an **integer** such that  $R^2 \equiv n \pmod{p}$ .

Figure 3: Highlighting key terms in the knowledge graph.

students, thereby further enhancing the effectiveness of OBE implementation in the course.

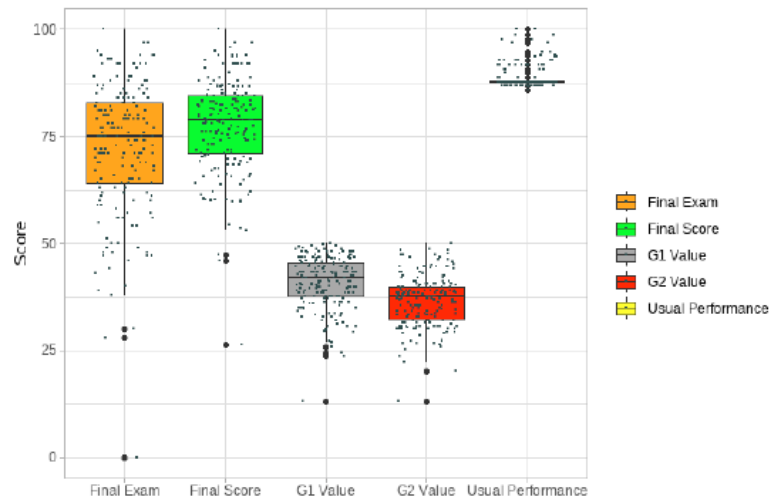
Recent longitudinal research underscores the sustainability and positive long-term impact of digital performance assessment in STEM education. By leveraging learning analytics and visualization tools, educators can systematically monitor student progress and adapt instruction to improve outcomes over multiple semesters or years. For example, Le *et al.* (2022) demonstrated that frequent interaction with digital assessment platforms and learning management systems is strongly correlated with higher academic achievement in mathematics and science, as revealed through detailed clickstream and performance

data analysis (Le *et al.*, 2022). Similarly, a multi-year study by Soto Rodríguez *et al.* (2021) found that computer-based assessments in science subjects produced student achievement outcomes equivalent to or better than traditional paper-based tests, with the added benefit of richer data for ongoing instructional improvement (Soto Rodríguez *et al.*, 2021). These findings highlight the value of integrating digital assessment systems not only for immediate feedback but also for supporting sustainable, data-driven educational reform in STEM disciplines.

Statistical methods play a crucial role in the analysis of learning data. By systematically comparing, analyzing, and interpreting learning outcomes, we can

Table 3: Summary of the “Number Theory and Combinatorics” course for the “CS-02” class. (G1: cultivating students’ abstract thinking ability; G2: applying knowledge of “Number Theory and Combinatorics” to analyze real-world problems and solve them using programming; there are 28 students in the “CS-02” class)

Final Exam	Usual Performance	Final Score	G1 Value	G2 Value
Min. : 0.00	Min. : 85.80	Min. : 26.34	Min. :13.17	Min. :13.17
1st Qu.: 64.00	1st Qu.: 87.80	1st Qu.: 71.14	1st Qu.:37.56	1st Qu.:32.24
Median : 75.00	Median : 87.80	Median : 78.84	Median :41.87	Median :37.52
Mean : 72.58	Mean : 88.84	Mean : 77.46	Mean :40.89	Mean :36.57
3rd Qu.: 83.00	3rd Qu.: 87.80	3rd Qu.: 84.44	3rd Qu.:45.37	3rd Qu.:39.77
Max. :100.00	Max. :100.00	Max. :100.00	Max. :50.00	Max. :50.00



**Figure 4:** Boxplot of achievement developed by students.

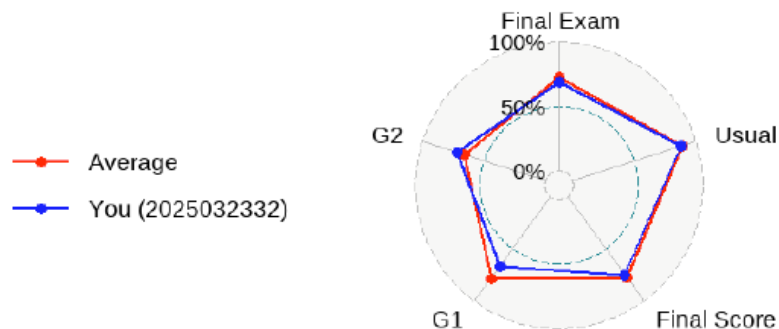
uncover underlying patterns and trends, thereby providing more targeted guidance and support for teaching. If learning outcomes indicate a significant decline in a class’s statistical performance, further tracking of the class’s teaching will be conducted to identify the causes of suboptimal learning outcomes. Additionally, we utilize our self-developed software to generate comprehensive statistical summaries of class-wide learning performance, as detailed in Table 3. Figure 4 presents the corresponding boxplot, which clearly illustrates the distribution of student outcomes.

**3.2. Student Engagement**

Despite the considerable potential of computer technology in education, its widespread adoption is often constrained by resource limitations. Sometimes we may lack the financial support to acquire advanced computer hardware or software, resulting in the underutilization of these technologies. To address these challenges, we adopted a self-developed approach, continuously refining the OBE experience by optimizing educational processes with in-house solutions.

Figure 5 shows the visualization in the form of radar charts which is developed by the students. The use of radar charts enables personalized analysis of individual student performance. This individualized approach allows both teachers and students to set specific learning goals and plans, and to adopt targeted instructional strategies and assessment methods tailored to each student’s needs.

Involving computer science students in the development of educational software offers multifaceted benefits that align closely with their professional and intellectual growth. First, it bridges the gap between theoretical knowledge and practical application. Unlike classroom exercises, software development for education requires students to tackle real-world challenges—such as tailoring features to diverse learning styles, integrating pedagogical principles into user interfaces, or optimizing performance for resource-constrained environments. This hands-on process deepens their understanding of core concepts like algorithms, data structures, and software architecture while teaching them to adapt technical solutions to human-centric needs.



**Figure 5:** Radar chart of achievement developed by students.

```

114 g1 <- coreData %>% select(x1)
115 colnames(g1)[1] <- 'Final Exam'
116 colnames(g1)[2] <- 'Usual Performance'
117 colnames(g1)[3] <- 'Final Score'
118 colnames(g1)[4] <- 'G1 Value'
119 colnames(g1)[5] <- 'G2 Value'
120 g2 <- pivot_longer(g1, cols = 1:5, names_to = "subject", values_to = "score")
121
122 pacman::p_load(showtext)
123 showtext_auto()
124 ggplot(g2, aes(x = subject, y=score, fill = subject)) +
125   geom_boxplot() +
126   scale_fill_manual(values=c("orange", "green", "darkgrey", "red", "yellow"))+
127   geom_jitter(width = 0.3, colour="#2f4f4f", size=0.5) +
128   labs(title="", x="", y="Score") +
129   guides(fill = guide_legend(title = "")) +
130   theme_light()

```

Figure 6: R code for visualization of Figure 4.

Moreover, it nurtures innovation and problem-solving agility. Educational contexts are dynamic—new teaching methodologies, technologies (e.g., AI-driven tutoring), or regulatory requirements emerge constantly. Students involved in such projects learn to prototype, test, and refine solutions rapidly, fostering a mindset of continuous improvement that is critical in fast-evolving tech industries.

#### 4. CONTINUOUS IMPROVEMENT AND FUTURE PLANS

In our OBE framework, continuous improvement is a dynamic, data-driven practice embedded at every stage of the educational cycle. Each semester, we align course objectives with measurable program outcomes. Post-course, we gather multi-source data—direct learning evidence, formative mid-term feedback, and industry advisor evaluations—to conduct gap analyses, identifying where performance meets or lags behind expectations. For instance, when gaps in interdisciplinary application emerged, we redesigned courses with updated case studies.

Looking ahead, our primary objective is to further enhance the effectiveness of OBE by integrating emerging technologies and continuously upgrading existing digital tools. For instance, the adoption of LLMs promises to make teaching strategies more intelligent, adaptive, and engaging. LLMs represent a significant breakthrough in artificial intelligence and offer multiple avenues for supporting and advancing OBE implementation. LLMs can be leveraged to identify students' emotional and cognitive states, while models such as the GPT series have demonstrated the potential to enhance students' mathematical reasoning abilities (Jia *et al.*, 2024). Furthermore, intelligent tutoring systems built upon the natural language processing capabilities of LLMs can provide students with real-time answers and personalized learning guidance, thereby helping them achieve their learning objectives more effectively (see Figure 6). LLMs can also analyze educational trends and student needs, automatically generate or optimize course content, and ensure that curriculum design remains aligned with expected learning outcomes. By facilitating the

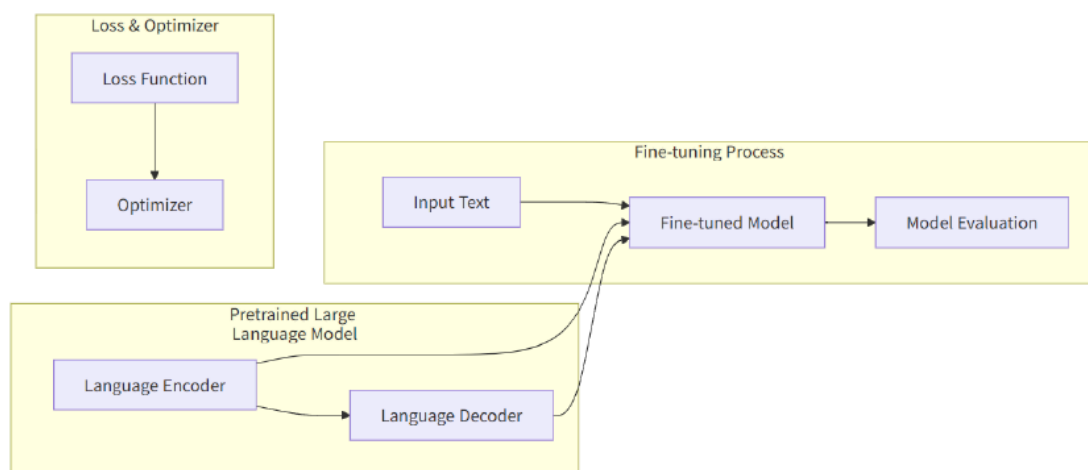


Figure 7: The plan of integrating large language models in on-line system.

integration of knowledge across disciplines, LLMs support interdisciplinary learning and the development of comprehensive competencies, which is consistent with the holistic development philosophy emphasized by OBE.

Recent advances in LLMs such as GPT have shown significant promise in enhancing mathematical learning, particularly in complex domains like number theory and combinatorics. LLMs can provide real-time, step-by-step explanations of abstract mathematical concepts, generate dynamic practice problems, and offer instant feedback tailored to individual student needs. Case studies have demonstrated that students using GPT-based tools for mathematics not only receive more personalized support but also show improved comprehension and problem-solving skills compared to those relying solely on traditional materials (Shahzad *et al.*, 2025). These findings suggest that integrating LLMs into mathematics education can bridge gaps in conceptual understanding and foster greater student engagement in challenging topics such as number theory and combinatorics.

## 5. CONCLUSION

This paper has presented a comprehensive case study of implementing outcome-based education in the “Number Theory and Combinatorics” course. Our experience underscores the critical importance of clearly defining learning outcomes, restructuring the curriculum, assessing teaching effectiveness through diverse and data-driven methods, incorporating active learning strategies, and providing robust support for students. We have demonstrated that the integration of computer technology — including knowledge graphs and advanced visualization techniques — not only enriches the learning experience but also enables more precise assessment and continuous improvement of student performance. By leveraging statistical analysis and visualization, we are able to track student progress, identify learning trends, and deliver targeted feedback. We encourage the student engagement in developing educational software. The participation strengthens students’ experience with tangible, impactful projects—demonstrating not just coding proficiency, but also the ability to create tools that drive meaningful change in education.

It should be mentioned that during our reform process, we encountered resistance—for example, teachers perceived the reform as adding significant extra workload. Other limitations include: Some academically struggling students felt that excessive statistical tasks further undermined their confidence in learning.

Our future plans highlight the potential of large language models for developing intelligent tutoring systems and the expanded use of knowledge graphs for personalized resource recommendation. Collectively, these innovations provide a strong foundation for designing adaptive, student-centered learning paths and advancing the goals of OBE in STEM education.

## DECLARATIONS

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