BREAKING BARRIERS: EMPOWERING NON-STEM STUDENTS IN DATA SKILLS THROUGH INQUIRY-BASED AND COLLABORATIVE LEARNING

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Abstract

Non-STEM students often undervalue critical data skills, erroneously perceiving them as exclusive to STEM disciplines. To address this misconception, tailored teaching approaches are essential for integrating non-STEM students into the learning process and enhancing their data skills. In the 2021-2022 academic year, an inquiry-based and collaborative learning approach was implemented in the Data Analysis, Tools, and Applications module, involving 140 students (23 computing, 117 business). The online session utilised Mentimeter for engagement, integrating real-world case scenarios, while a 2-hour on-campus practical session focused on collaborative problem-solving. Evaluation included a self-directed questionnaire and a formative test covering various learning levels. Of the 117 business students, 35% responded to the questionnaire, expressing strong positive opinions on lectures, the inquiry-based approach, visual aids, instruction, and assessments. The formative assessment revealed an average score of 20.64 out of 35, with no significant difference between STEM and non-STEM students. The results indicate a reduced skill gap by the study's end, highlighting that non-STEM students can attain data skills akin to STEM counterparts. Inquiry and collaborative learning positively impacted non-STEM students, showcasing the potential for effective teaching of foundational data skills through appropriate methods. The 'learning by doing' approach emerged as instrumental in breaking down disciplinary barriers, emphasising the need for broader exploration and implementation of such methodologies in education across diverse settings.

Keywords: Non-STEM, Data Skills, Inquiry-based learning, Collaborative Learning

1 INTRODUCTION

The Royal Society's labour market analysis [1] highlights a substantial demand for individuals possessing data skills, especially specialists, across diverse organisations, from government departments to technology start-ups. The UK has witnessed a significant surge in demand for workers with specialised data skills, experiencing a 231% increase over the past five years. To meet employer needs, it is imperative to ensure our education system equips all young individuals with data knowledge and skills. Facilitating the exchange of talent between academia, the public sector, and business is crucial, along with responsibly widening access to data. Traditionally associated with STEM fields, data skills, encompassing the ability to collect, organise, and interpret data [2], are deemed essential in the 21st century skills [3]. Despite their significance, there's a misconception that data skills are exclusively for STEM students. However, these skills are applicable to non-STEM jobs as well. To bridge the gap, an effective strategy could involve incorporating more STEM education into non-STEM disciplines, enabling non-STEM graduates to qualify for jobs within their respective fields [4]. To dispel this misconception, tailored teaching approaches are vital for integrating non-STEM students into the learning process and enhancing their data skills. The pedagogical approach adopted for teaching foundational data skills in non-STEM courses is based on 'learning by doing,' relying on inductive teaching methods. This approach aims to make non-STEM graduates proficient in data skills and ready for the evolving demands of the job market.

Research suggests that inquiry-based learning involves establishing a classroom culture that cultivates students' inquiry habits of mind, fostering curiosity and critical thinking. This method effectively keeps students stimulated, inquisitive, and engaged in the learning process [5]. Numerous studies have explored the application of inquiry-based learning to enhance students' skills in various domains. For instance, Vlasenko et al. [6] implemented a workshop based on inquiry-based learning to facilitate scientific research activities in mathematics, finding that students increased their interest in research content and activities. Similarly, a study on implementing inquiry-based learning with middle and high school students to teach game design demonstrated increased engagement frequency, motivation, and self-efficacy [7]. Research by Tambak et al. [8] focused on the effect of inquiry-based learning on

academic writing skills, revealing overall improvement without gender-based differences. Additionally, inquiry-based learning in higher education, specifically in the criminology discipline, showed that both inquiry-learning protocols promoted engagement in scientific practices [9].

Collaborative learning is an educational approach involving groups of learners working together to solve problems, complete tasks, or create products [10]. This method has been applied across various domains to enhance students' learning performance through active learning activities. For example, Sumtsova et al. [11] implemented collaborative learning in foreign language education for engineering students, observing that it promoted the development of communication skills, individual reasoning, and the ability to perform various social roles in collaborative activities. Another study explored the factors influencing students' learning performance through collaborative learning, concluding that engagement with social factors enhances students' learning activities. Learning in groups with classmates proves beneficial, as it leads to quality outcomes, with students building powerful concepts and ideas through group discussions and interactions with peers or instructors [12].

Considering the benefits of both inquiry-based learning and collaborative learning, these approaches can be combined to facilitate constructive learning through active group discussions and interactions with peers and instructors. For instance, Korkman's work [13] examined the effects of inquiry-based collaborative learning and inquiry-based online collaborative learning in the context of chemistry. The study revealed that both methods significantly improved students' success, resulting in higher post-test scores compared to pre-test scores. Another study investigated the outcomes of implementing collaborative-based inquiry learning models for the development of metacognitive abilities in elementary school students. The research demonstrated the feasibility and effectiveness of the collaborative-based inquiry learning model from both experts' and users' perspectives, leading to improved metacognitive abilities in students [14]. Similarly, Adhami et. al. [15] explored the integration of inquiry-based learning and computer-supported collaborative learning in a flipped classroom for academic writing in railway engineering. The study utilised Edmodo and Google Docs as collaborative platforms, implementing inquiry-based learning across five phases. The integrated approach outperformed in terms of grammar and fluency.

Therefore, in our study, we also incorporated both inquiry-based learning and collaborative learning to teach data skills to non-STEM students.

2 METHODOLOGY

This section outlines the methodology adopted in this study, detailing the composition of the participant group, the employed teaching pedagogy emphasising inquiry-based and collaborative learning, and the comprehensive assessment of students' performance and opinions regarding the teaching and learning approach implemented.

2.1 Participants

The Data Analysis, Tools, and Applications module had a total enrollment of 140 students, with 23 of them in a STEM course (computing) and the remaining 117 in a non-STEM course (Business). Table 1 presents a detailed breakdown of the number of students across different courses of study.

Table 1. Breakdown of student numbers from various courses

Course of Study	***Number of Students***
Accountancy and Finance	24
Business Management	48
Business Management with Digital Technologies	10
Business Management with Finance	7
Business Management with Marketing	21
International Business Management	7
Computing	23
Total	140

2.2 Inquiry-based learning and collaborative learning

The teaching covered a range of topics, encompassing Introduction to Data Analysis, Foundations of Data Analysis, Data Collection, Data Preparation, Descriptive Statistics, and Data Visualisation. The teaching and learning approach incorporated an inquiry-based method during live online sessions. In these sessions, students actively engaged in a short lecture, explaining the weekly topic's concept, followed by participatory questioning activities using Mentimeter, an interactive tool embedding quizzes, word clouds, or polls. This method as shown in Figure 1, conducted on smartphones or computers, facilitated student connection to the presentation for answering questions and addressing real-world case scenarios, effectively reinforcing their knowledge. Following the online lecture, students transitioned to a 2-hour on-campus practical session, divided into two parts for individual tasks and group work. The first hour focused on individual activities, providing case studies to enhance comprehension of concepts covered in the online lecture and application of knowledge to practical skills. The second hour implemented collaborative learning, with groups working collectively on tasks relevant to the week's topic. This approach involved brainstorming and teamwork to find effective solutions.

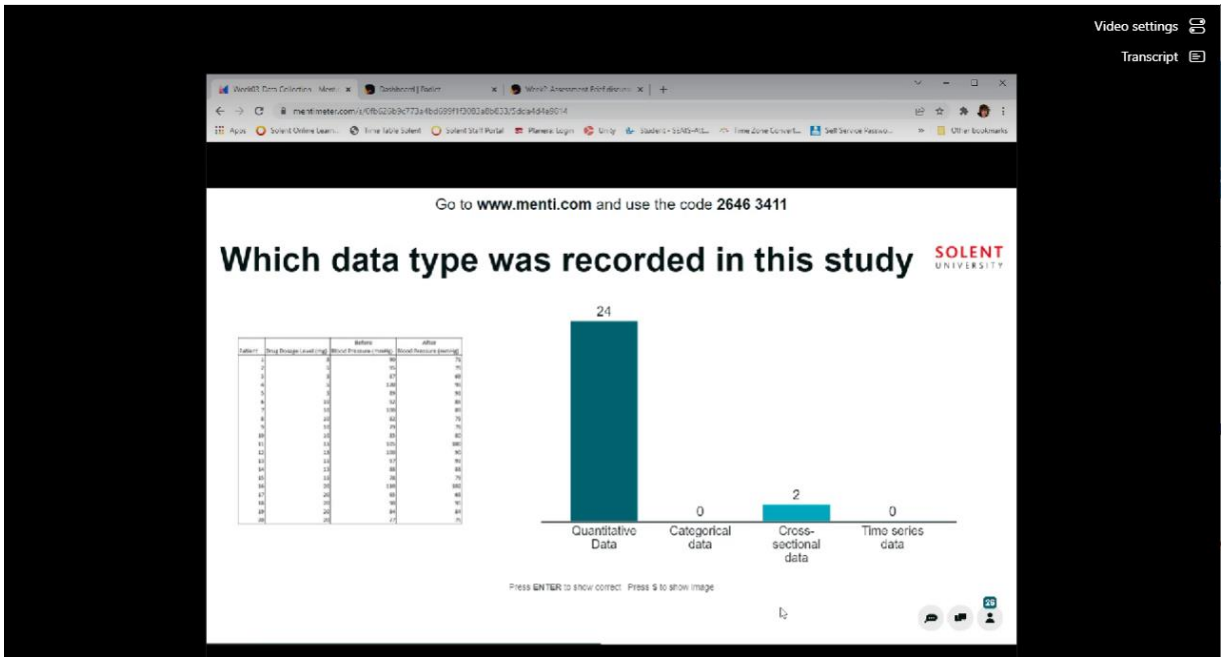

Figure 1 Example of interaction response from students during the inquiry process

2.3 Inquiry-based learning and collaborative learning evaluations

A survey was conducted at the conclusion of the teaching period to collect feedback on students' opinions. Additionally, a post-teaching formative test was administered to assess the students' proficiency in data knowledge and skills.

2.3.1 Inquiry-Based Learning and Collaborative feedback Survey

To gauge students' perspectives on the inquiry-based and collaborative learning approach, we employed a self-directed questionnaire adapted from the National Research Council [16]. The questionnaire aimed to discern opinions across various aspects of the learning process, including students' evaluations of lecture sessions, visual aids, participation in activities, learning support materials, assessments, as well as their personal assessments of learning pace, content difficulty, and overall learning amount. Students were asked to provide comprehensive ratings for each teaching aspect under consideration.

2.3.2 The Post-teaching Formative Assessment

The formative test conducted after the teaching sessions was designed to evaluate students' comprehension of the taught topic. Administered within a time-constrained format of 30 minutes, the test comprised a total of 26 questions. It took place in the computer lab during the practical session on campus. The questions were strategically crafted to assess various levels of learning, incorporating multiple styles such as Multiple-Choice Questions (MCQ), Drop-in Answers, and fill-in-the-blank. This

assessment framework, aligned with the revised Bloom's Taxonomy [17], aimed to measure students' learning across different cognitive levels, including recalling information, summarising ideas, and applying knowledge to solve new problems.

3 RESULTS

The results section provides an analysis of the effectiveness of the inquiry-based learning and collaborative learning approaches, presenting findings derived from feedback obtained through questionnaires assessing student opinions and insights into these pedagogical methods. Additionally, the section presents the outcomes of the post-teaching formative test, shedding light on students' understanding of the topics covered.

3.1 Inquiry-based learning and collaborative learning feedback results

Out of the 117 business students (non-STEM), 35% (41 students) participated in the questionnaire. The results as shown in Figure 2 indicate that 59% of students found the lecture session satisfactory. Regarding the interaction and discussion implemented as an inquiry-based and collaborative learning approach, 47% of students commended this aspect. Similarly, 48% of students gave a commendable rating to the visual aids, where interactive tools like Mentimeter were used for delivering lectures. In terms of instruction and online materials, 55% of students rated them as satisfactory, and 62% rated the assessments as satisfactory. Overall, students expressed strong positive opinions about the inquiry-based and collaborative learning approach.

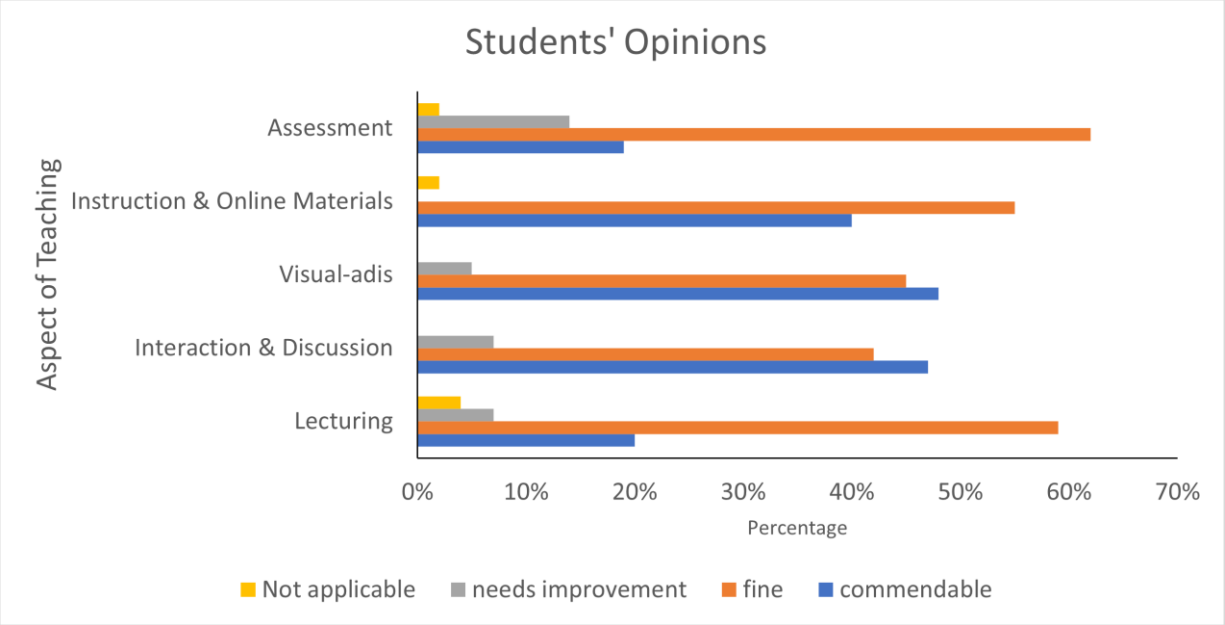

Figure 2 Students' Perception of the Inquiry-Based and Collaborative Learning Approach

Additionally, students shared their opinions on the learning experience. Figure 3 illustrates that 55% of students believed the learning pace was suitable, and 55% found the content difficulty manageable, as shown in Figure 4. 52% of students expressed they gained knowledge to a fair extent from the learning process as shown in Figure 5.

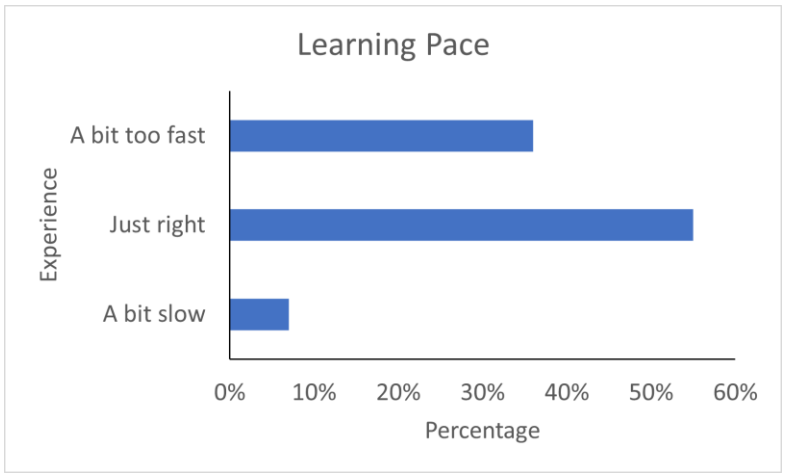

Figure 3 Students' Learning Pace Experience

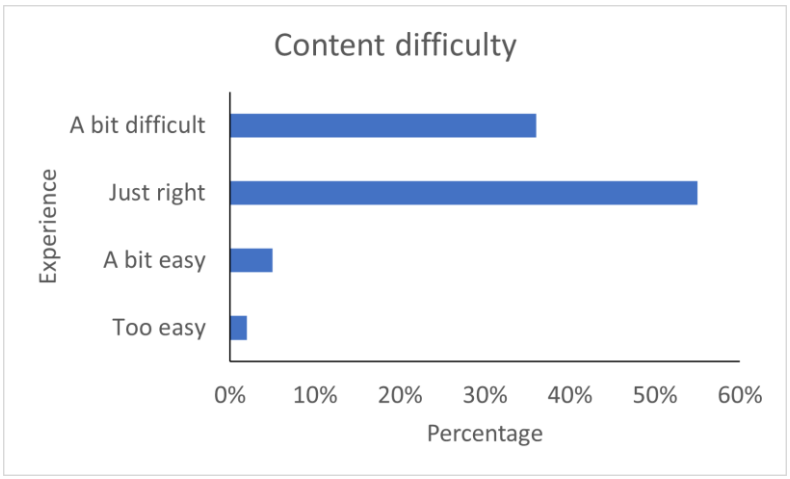

Figure 4 Students' Experience with Content Difficulty

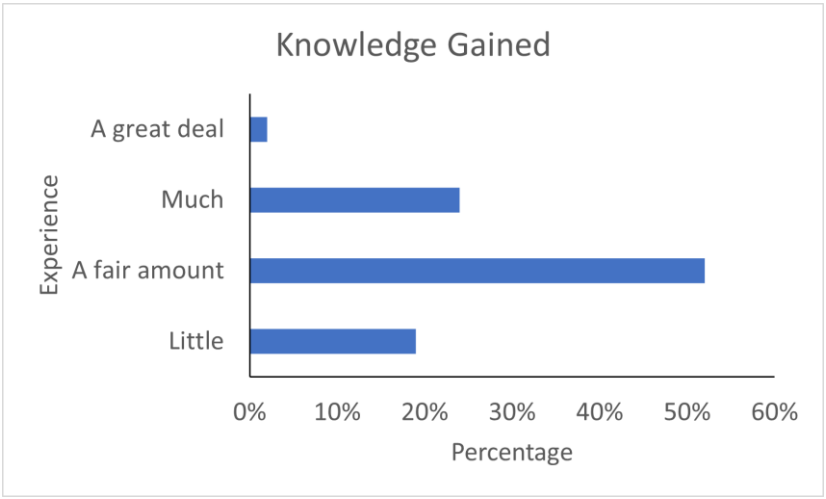

Figure 5 Students' Experience of Knowledge Gained from Learning

3.2 The post-teaching formative assessment results

A total of 76 students participated in the formative assessment, yielding an average test score of 20.64 out of 35 (SD = 5.323), as illustrated in Figure 6.

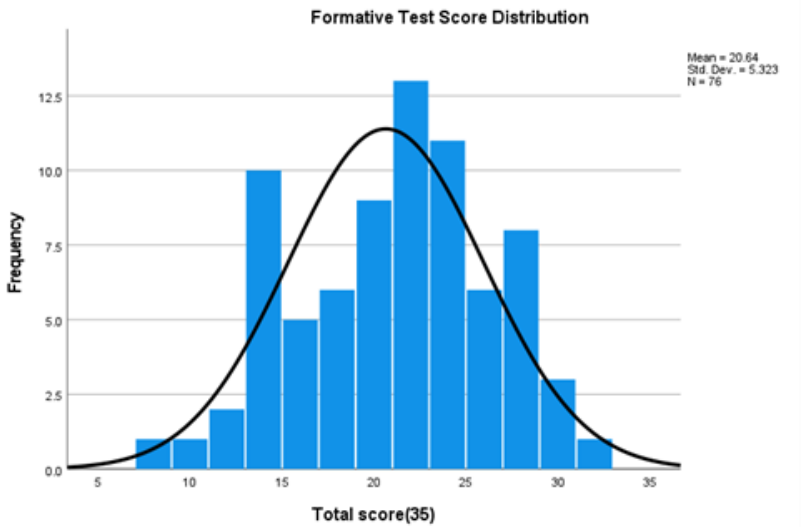

Figure 6 Histogram of Formative Assessment Scores

The formative assessment results were further examined for STEM and non-STEM students. An independent sample t-test was employed to compare their average formative test scores, revealing no significant difference (t(74) = -1.66, p = .10), despite STEM students (M=22.85, SD=6.22) scoring slightly higher than non-STEM students (M=20.19, SD=5.06) as shown in . These findings suggest no significant disparity in data skills between the two groups.

Table 2 t-Test Results Comparing Formative Test Scores between Non-STEM and STEM Students

	non-STEM		***STEM***		***df***	***t***	***p***	***Cohen's d***
	M	***SD***	***M***	***SD***				
Formative Test	20.19	5.06	22.85	6.22	74	-1.66	.10	-0.51

4 CONCLUSIONS

The study highlighted the positive impact of inquiry-based and collaborative learning on non-STEM students, enabling them to acquire data skills typically associated with STEM disciplines. Students expressed a preference for interactive and collaborative classroom environments, believing they learned more effectively when utilising tools like Mentimeter to engage with their mistakes. Importantly, there was no significant difference in knowledge acquisition between STEM and non-STEM scores, indicating that foundational data skills can be effectively taught to non-STEM students with suitable methods. Effective teaching methods, particularly the 'learning by doing' approach, play a crucial role in overcoming disciplinary barriers and facilitating a seamless transfer of knowledge and skills. These findings underscore the importance of exploring and implementing inquiry and collaborative-based methodologies in education across diverse settings, with the aim of enhancing student learning.

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