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Analysing Learning Styles for Engineering Capstone Projects: 4MAT Analysis on Student Outcomes and Perceptions

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Abstract. Capstone projects are integrated into engineering curricula to combine various subjects and impart essential professional skills that may be difficult to teach solely through traditional lecture-based courses. These projects play a crucial role in preparing students for their future roles as professional engineers, thereby significantly impacting a university's industry reputation and ranking. The challenge in engineering education lies in aligning the teaching approach of educators with the diverse learning styles of their students. This study aims to examine the impact of the learning style of the students measured by their watching-doing scores using the 4MAT tool, on the attainment of the benefits of the graduation project (GP). The Bayesian Belief Networks (BBN) approach was adopted in this study to analyse the data collected from 271 students enrolled in both GP1 and GP2 semesters in the engineering department of United Arab Emirates University. Results show that regardless of learning style, both watching and doing category students share similar perspectives on various aspects of the GP course, such as the optimal team performance ratio. However, when assessing the overall effectiveness of the GP programme, doing students exhibit a higher level of agreement than watching students. The study provides valuable insights to faculty members, helping them navigate the optimal balance between providing mentorship and fostering students' independence during the different stages of their final-year design capstone projects. These findings underscore the importance of tailored educational strategies to accommodate diverse learning styles, contributing to more effective engineering education and better-prepared graduates.

Keywords: Bayesian Belief Networks; Capstone project; Education; Engineering; 4MAT system

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1. Introduction

Capstone design courses are a pivotal aspect of engineering education, typically occurring in the final year of undergraduate studies. These projects aim to integrate and apply the knowledge and skills students have acquired throughout their academic journey. Traditionally, engineering curricula involve major group or individual design projects, to develop professional engineering skills, including data interpretation, theoretical application, problem-solving, design proficiency, multi-disciplinary teamwork, effective communication, and ethical awareness (Qattawi et al., 2019). The capstone projects present students with a simulated but well-regulated environment where they can collaborate as a team, tackle challenges, and evaluate their work's quality through testing and validation. To support these endeavours, students are encouraged to interact with a development environment that closely resembles industry practices (Howe & Goldberg, 2019).

These goals are outlined in programme outcomes and assessments by university accreditation organisations, and capstone courses have long been a requirement for fulfilling undergraduate accreditation criteria. Capstone projects are considered high-impact practices that boost student performance. They are characterised by demanding significant time and effort, offering learning opportunities outside the classroom, fostering meaningful interactions with faculty and peers, encouraging engagement with diverse individuals, and providing frequent and valuable feedback (Elwell et al., 2021). Employers highly value effective capstone projects, as they prepare graduates with the practical knowledge needed for success in their professional careers. As a result, it is essential to identify the elements that contribute to the efficacy of capstone programmes (Ward, 2013).

Teaching methods vary significantly among professors, with some relying on lectures and others choosing to demonstrate concepts. Some educators emphasise fundamental principles, while others prioritise real-world applications. Each of these teaching styles brings value and importance to the educational experience. Similarly, students adopt diverse learning styles. Some prefer visual and auditory learning, while others thrive through hands-on activities and reflective practices (Parul et al., 2021). Intuitive problem-solving and logical reasoning are among the different approaches students use to grasp knowledge effectively. All of these learning styles are equally valid and contribute productively to the learning process. Because of the wide array of teaching and learning styles, mismatches can occur between instructors and students. When such mismatches happen, both students and professors may encounter challenges in the educational journey (Kapadia, 2008).

Recognising that students have different learning styles, educators often adopt learner-centred principles to facilitate effective student interaction. To achieve this, the educator needs to analyse the preferred learning style, strengths, and weaknesses of the students (Dick et al., 2005). Accommodating the diverse learning styles of the students is important as it reflects how the students perceive, interact, and respond to the knowledge provided. Knowing the learning styles is crucial to improve the quality of education (Felder & Spurlin, 2005). Thus, students' learning styles are becoming increasingly important when analysing their behaviour. Among different learning style models, this study adopts the 4MAT system to analyse the learning style of the students as it has been used widely in engineering education for many years (Obaya-Valdivia et al., 2023).

In the context of rapidly evolving engineering education, the successful execution of capstone projects is crucial for preparing students for their future careers. However, there is an urgent need to address a critical gap: the relationship between students' learning styles and the outcomes of these projects is not well understood. This gap poses a significant challenge, as traditional teaching methods may not cater to the diverse learning styles of students, potentially limiting the effectiveness of capstone projects. To bridge this gap, it is essential to explore how different learning styles impact the attainment of capstone project outcomes. Using the 4MAT tool to measure learning styles through watching-doing scores and analysing data from 271 students at the United Arab Emirates University with BBN, this study aims to shed light on these dynamics. The capability of the BBN approach to explore the correlations among the variables taking into account associated uncertainty and complexity enables the attainment of these objectives. The following research questions guide this investigation: How do varying learning styles, as determined by the watching-doing scores, influence students' perceptions of the effectiveness of the capstone project (GP) course? What is the impact of different learning styles on students' achievements and overall performance in the GP course? How can educators adapt their teaching strategies to better align with diverse learning styles and enhance the success of capstone projects? By addressing these questions, this study seeks to provide a comprehensive understanding of the interplay between learning styles and capstone project success, ultimately contributing to the improvement of engineering education.

2. Literature Review

2.1 Capstone project

The terms "capstone project" and "graduation project" are often used interchangeably in this study. Capstone projects are comprehensive, culminating academic experiences that typically occur in the final year of undergraduate studies. These projects require students to apply their theoretical knowledge and practical skills to solve real-world problems. However, graduation projects, also commonly referred to as GP, are similar to capstone projects but may have specific requirements or focuses depending on the academic institution (Halim et al., 2014).

The GP aids the students to integrate their learning, be involved in team-based work, and equip themselves for the challenges in the real world (Sullivan et al., 2013). The graduation project involves carrying out project work by the students usually over a period of two terms which ends with the preparation of a report and oral presentation by the students. The educators evaluate the work done by the students based on rubrics which include various performance criteria of the students including project assessment, presentation of the results, and so on.

Tuysuzoglu et al., (2015) analysed 21 rubrics to evaluate the influence of rubrics on the overall grades of graduation projects using machine learning methods among the students belonging to the Computer Engineering Department. It was estimated from the study that the rubrics "Overall performance" and "References" had the highest and lowest impact on the gradation project grades respectively. In addition, the 21 rubrics were grouped into three general categories: project assessment, presentation assessment, and project report assessment. Among them, project assessment had a higher correlation to the overall grade of the student followed by the presentation and project report assessment. Hence, it was evident that the overall performance of the students needs to be focused on while evaluating the effectiveness of the GP.

Scott et al. (2014) analysed the relationship between student performance and their learning style. The learning styles of 33 students based on the Felder-Silverman Learning Style Model were recorded and the data mining approach using association rules was adopted to discover how the student performance aligns with their learning styles. It was found that there is a significant relationship between student engagement and success in the GP and their learning style. The correlation between the faculty and student learning style and how the learning style influences the student perception and success in a business capstone course with Kolb's Learning Style Model was explored. Both the student-focused approach, where the learning styles of the students are taken into consideration and the teacher-based approach, where more emphasis is given to the educator were analysed separately. It was revealed that the student-focused approach in which the teaching methods are aligned with the students' learning styles/preferences leads to higher student satisfaction and achievement of the learning outcomes.

2.2 The 4MAT system

Students have diverse motivations for learning, influenced by their individual experiences, peers, parents, and career interests. Nonetheless, teachers can significantly benefit from understanding their students' learning styles, as it enables them to identify topics that naturally and immediately captivate their interest (Abdullah et al., 2024). Consequently, educators can opt for subjects, areas, and qualifications that are more likely to engage students, and effectively communicate, considering how their students perceive information and learn best. They can also choose suitable teaching styles and learning environments that keep students motivated and adapt their teaching approach in certain situations to better accommodate their students' needs (Panezai & Mahmood, 2022).

The 4MAT system developed by McCarthy incorporating Kolb's learning style theory depicts the learning cycle. The 4MAT system was adopted to improve engineering education and subjects including Science, Business, and others (Tezcan & Güvenç, 2017). The system categorises the learners based on their learning style as innovative learners, analytic learners, common-sense learners, and dynamic learners, and it enables the educators to consider the learning style/preferences of the students, ensuring active participation of students in the learning process (Yanti et al., 2021).

The 4MAT system assists educators in structuring their teaching methods to align with the diverse learning styles of students. (Naveen, 2021). People perceive and respond to reality in varied ways: some rely on their senses and feelings, while others think things through. Beyond perception, individuals also differ in how they process information and integrate new knowledge. Some students are more inclined to be watchers, reflecting on information and carefully choosing perspectives before acting. In contrast, others are doers, immediately taking action and then reflecting upon their experiences. This processing dimension forms a continuum from internalising to acting, with both approaches having their strengths and weaknesses (Nicoll-Senft & Seider, 2009).

Balancing both perceptive styles and processing approaches can significantly enhance the learning journey. Watchers can improve their reflective abilities and develop the courage to experiment, while doers can refine their hands-on skills and cultivate patience for reflective observation. This study's categorisation of students into "watching" and "doing" aligns with Kolb's Learning Theory, where "watching" students prefer reflective observation, and "doing" students thrive on active experimentation. Understanding these styles helps educators design curricula that cater for diverse learners, thereby enhancing the overall educational experience and the effectiveness of the GP programme (Irfan et al., 2016).

2.3 Bayesian Belief Networks

A BBN is a graphical model representing the relationships among the variables and the probabilities associated with them. BBN structures are directed acyclic graphs (DAG) with nodes representing the variables involved and arrows representing the relations among the variables. Based on the available data, prior probabilities are initially assigned to the nodes which are further updated based on the new data. BBN methods are useful in modelling complex systems involving uncertain and incomplete information (He et al., 2022). In addition, the ability of the BBN method to handle missing data has extended its application level. BBN models can address the uncertainty through causal and probabilistic relationships among the variables (Laurila-Pant et al., 2019). Bayes' theorem forms the basis of BBN analysis represented by equation (1).

$$P(A \mid B) = \frac{P(A) * P(B \mid A)}{P(B)} \quad (1)$$

Where $P(A \mid B)$ is the conditional probability of event A given event B, $P(A)$ is the probability of event A, and $P(B)$ is the probability of event B. As given in the above equation, knowing the probability of an unknown event based on the probability of a known event could generate insightful inferences for decision-making

In this study, we propose to combine the learning style of the students analysed from the 4MAT system with the outcomes of the capstone programme and the perceptions of the students on the effectiveness of the programme. The BBN method, considering its strength in addressing uncertainty and probabilistically estimating unknown parameters, is adopted to explore the impact of the learning style of the student on the overall attainment of the outcomes of the programme.

3. Methodology

The framework of the analysis performed in this study is provided in Fig 1. In the first phase, data is collected through a questionnaire survey among the students. In the second phase, the data collected is pre-processed to prepare for the analysis. In the third phase, the data analysis is performed based on the BBN approach, and interpretations are made to provide recommendations to improve the GP course structure for the benefit of the students and faculty members.

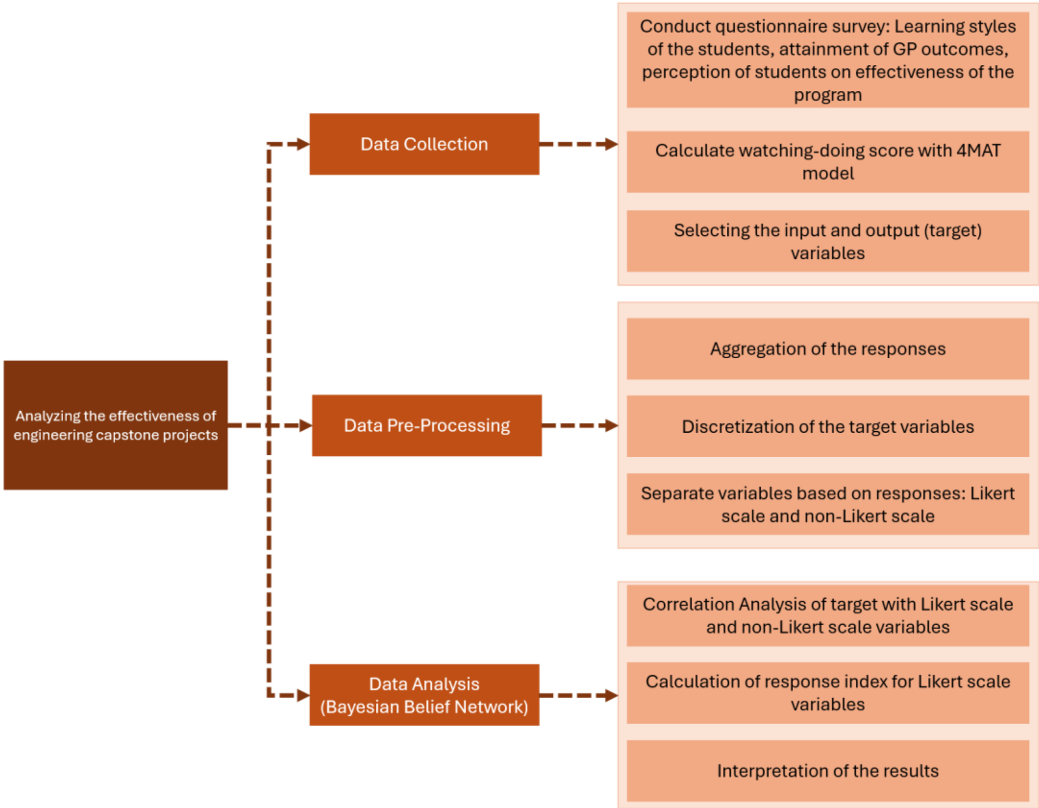


Figure 1: Overall framework of analysis

3.1 Data collection

3.1.1 Questionnaire survey

In the first phase, a questionnaire survey was designed to understand the learning style of the students. The questionnaire survey was conducted among 271 students from the College of Engineering, including students from various engineering disciplines and both GP1 (first term) and GP2 (second term) students. The sampling methodology employed in this study ensured that students from various engineering disciplines were proportionately represented, thereby capturing a diverse range of perspectives and learning styles. The engineering department at United Arab Emirates University (UAEU) has a substantial number of students enrolled in various streams. The exact number of 271 participants was determined based on the students who were readily available and willing to participate in the study.

The survey mainly focused on recording the responses from students on the attainment of different outcomes of the GP programme, and the perception of the students on how the capstone project course contributed to their learning and skill development. The outcomes studied were adapted from the course outcomes prescribed in the curriculum. The survey also included questions related to the general learning style of the students adapted from the 4MAT system. The watching-doing score was calculated based on the responses provided by students to the questions related to their learning style as per the 4MAT model. In total, there were 30 questions in the survey covering various aspects of the capstone project course. The data collected from the survey was analysed to identify patterns and trends among the responses. Table 1 lists the survey questions and their possible responses.

Table 1: Questionnaire Data Overview

No	Question	Category	Responses
1	What is your discipline?	Other	• Chemical/Petroleum engineering • Civil & environmental engineering • Electrical/Communication engineering • Mechanical/Aerospace engineering • Other
2	Are you currently enrolled in GP1 or GP2?		• GP 1 • GP 2
3	Ability to comprehend the theoretical background of a contemporary engineering problem	Outcomes of the GP programme	• Agree • Disagree • Neutral • Strongly agree • Strongly disagree
4	Ability to apply the fundamentals of engineering design practices and procedures including the assessment and evaluation of alternative engineering solutions		
5	Ability to develop and conduct appropriate experimentation modelling simulation and/or data analysis using modern engineering tools		
6	Ability to communicate effectively through oral and written presentations		
7	Ability to embrace the principles of engineering ethics and recognise social and environmental responsibilities		
8	Ability to recognise the need for additional knowledge acquisition and integrate this knowledge effectively		
9	Ability to develop leadership skills and project management techniques so as to perform independently in a real work		

	environment		
10	Ability to work collaboratively in a teamwork context		
11	In your opinion how much time should be dedicated for a graduation project on a weekly basis?	Perceptions of the students	• Below 4 hours/week • 4-6 hours/week • 6-8 hours/week • 8-12 hours/week • Above 12 hours/week
12	In your opinion which of the following ratios will help students perform best as a team?		• 2 students per advisor • 3 students per advisor • 4 students per advisor • 5 students per advisor • 6 students per advisor • 7 students per advisor
13	The GP improved my understanding of the courses related to the project area		• Agree • Disagree • Neutral • Strongly agree • Strongly disagree
14	The GP improved my teamwork and collaboration skills		
15	The GP improved my self-regulation & self-learning skills		
16	The GP improved my communication skills		
17	The GP prepared me for a professional career and lifelong learning success		
18	The GP allowed me to apply the knowledge I have gained from the degree courses		
19	Working in groups through the GP was enjoyable		
20	When learning I prefer	Learning Style of the Student	• A quiet environment • An active environment
21	When learning I prefer to		• Act and then reflect • Reflect before I act
22	I tend to		• Keep a lot inside • Talk out my ideas
23	I am		• Private • Public
24	I prefer to		• Evaluate • Initiate
25	Generally, I am		• Action-oriented • Reflective
26	When solving problems, I		• Experiment • Ponder
27	Generally, I am		• Energetic • Reserved
28	Generally, I am		• Quiet • Talkative

29	I tend to be more		• Extroverted • Introverted
30	I prefer learning tasks that are		• Group • Individual

3.1.2 Calculation of watching-doing score

The watching-doing score is a numerical representation used to quantify the level of engagement or participation of individuals in an activity. It distinguishes between people who are likely to be observed (watching) and those who actively participate (doing). The 4MAT model is adopted in this study to identify and analyse the learning preferences of the students based on their responses to questions related to learning styles in Table 1.

The calculation of the watching-doing score involves understanding the type of learner based on the 4MAT tool, which categorises learners into four types (innovative learners, analytic learners, common sense learners, and dynamic learners) resulting in a four-quadrant model. The watching-doing score serves as the output node, calculated through the analysis of a questionnaire survey, reflecting the learning style of the students. In the subsequent sections, we analyse how the learning style reflected by the watching-doing score is influenced by the GP outcomes and the perceptions of the students. Since the watching-doing score is estimated based on the learning style of the student, the nodes belonging to the learning style category are not further considered in the following analysis.

The watching-doing score was calculated for 271 students. In this study, this score is considered as the target variable to analyse the learning style of the students and its influence on the GP outcomes and perceptions of the students. The target, watching-doing score ranges from 11 to -11 with values: 11, 9, 7, 5, 3, 1, -1, -3, -5, -7, -9, -11. Among these, the watching score is more towards negative numbers as it represents more introverted or reserved students. On the other hand, doing score is more towards positive numbers as it represents more extrovert students. The probability distribution of the watching-doing score of the students is provided in Fig 2.

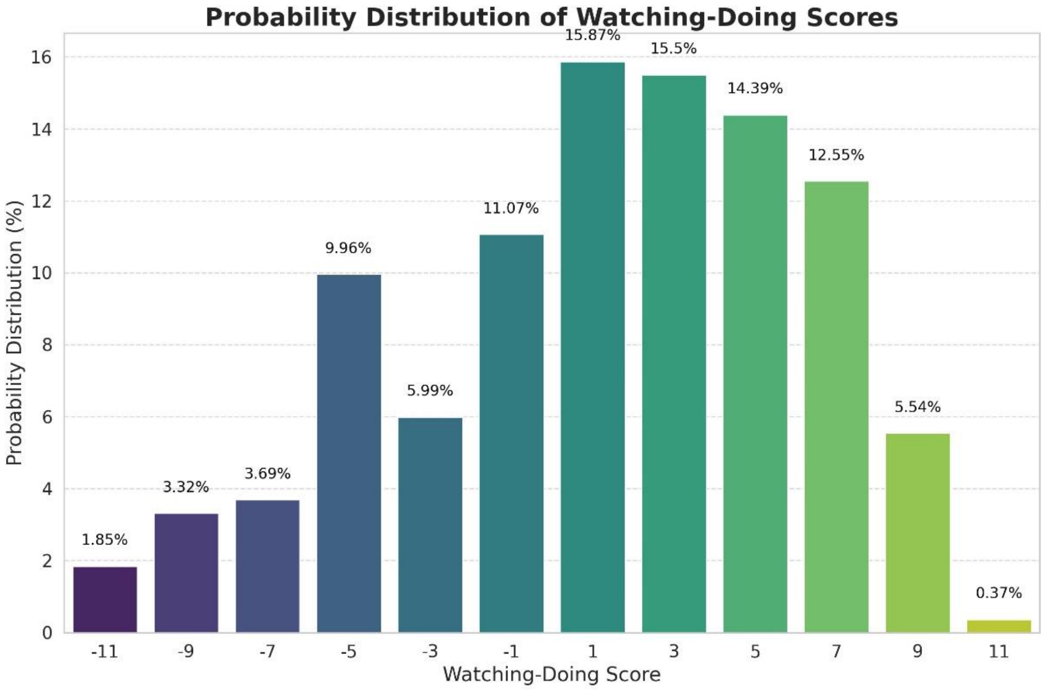


Figure 2: Probability distribution of the watching-doing score (target variable)

3.1.3 Selection of input and output variables

As provided in Table 1, the data collection involves 30 variables along with the watching-doing score of each student. The watching-doing score obtained is considered as the target/output variable. Since the watching-doing score is determined from the learning styles of the students, the variables related to learning styles are not considered further. The rest 19 variables in Table 1 are considered as the input factors for further investigation.

3.2 Data Pre-processing

Before analysing the data, certain pre-processing steps are performed as outlined below.

3.2.1 Aggregation of the Responses

The probability distribution of the variables involved in the study was calculated. It was noted that the proportion of responses 'Disagree' and 'Strongly disagree' is very low compared to other states. Hence, these two classes are aggregated.

3.2.2 Discretisation of the target variable:

The watching-doing score is treated as a continuous value and is discretised into three states: Watching, Neutral, and Doing, as shown below:

- Watching ranges from -3 to -11
- Neutral ranges from 1 to -1
- Doing ranges from 3 to 11

The classes are renamed as shown in Figure 3.

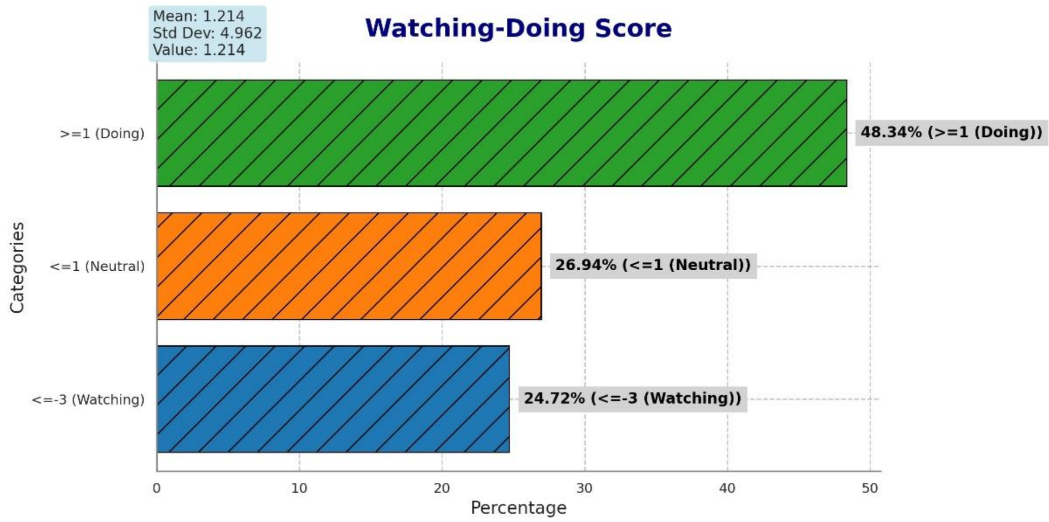


Figure 3: Discretisation of the target node.

3.2.3 Separate Variables based on Responses

The responses to the 19 variables included in the study were recorded in different formats. Some of them were recorded on a Likert scale and others on a non-Likert scale. The variables that were recorded in the Likert scale (strongly disagree to strongly agree) and non-Likert scale (categorical responses, numerical values, etc.) were analysed separately. Among the 19 variables, responses related to students per advisor ratio, the optimum time to be allocated for GP on a weekly basis, the discipline of the student, and the currently enrolled GP term were recorded on a non-Likert scale. The rest 15 variables were recorded on the Likert scale.

4. Results

This section presents the results of the BBN analysis and interpretation of the results. Supervised learning was initiated to explore the influence of the watching-doing score on the GP outcomes and perceptions of the students. For this, two scenarios were considered: (1) the response of the students who completely belong to the watching category, and (2) the response of the students who completely belong to the doing category. The representation of these scenarios in the Bayesian analysis platform is given in Figure 4 to Figure 7.

4.1 Correlation analysis of target variable with input variables

4.1.1 Nodes recorded in the non-Likert scale

The extent of influence of the parameter concerning the target node is given below:

- Students per advisor ratio: The responses provided by the students on their opinion of the best ratio of students to advisors are given in Figure 4. Among the complete responses, the students who completely belonged to either the watching category or doing category were separately analysed. Responses of the students who belonged to the neutral category were not considered. Among the students who belonged to the watching category, 53.73% of them believed that the best ratio is four students per advisor. Similarly, among the students who belonged to the doing category, the percentage of students who voted for four students per advisor is 58.02%. Hence, more than 50% of both the watching and doing category of students agreed that the best ratio of students to perform as a team was four students per advisor.

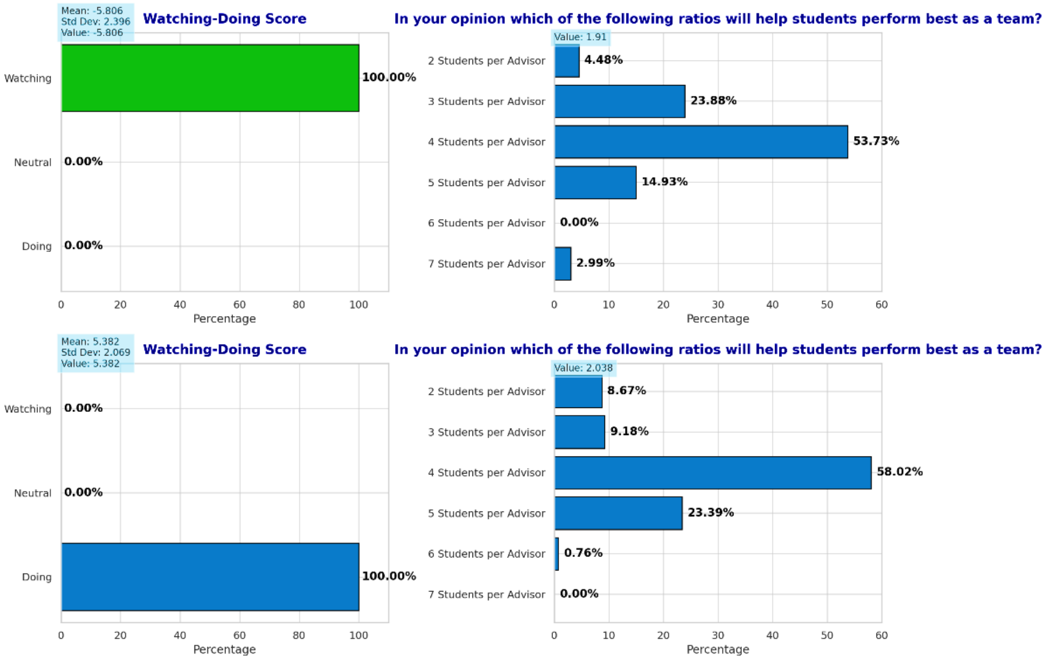


Figure 4: Students per advisor ratio.

- **Area of study:** While comparing the departments of the students who were watching and doing, there was a slight dominance of Civil & Environmental Engineering for the watching category and dominance of Chemical/Petroleum Engineering for the doing category as shown in Figure 5.
- **Hours per week:** It is important to know the optimum time to be dedicated to the graduation project so that the students may not be distracted from other courses (Bielefeldt et al., 2011). In the case of the watching category, more students agreed with the time of 6-8 hours per week. On the other hand, the responses of doing category students were equally distributed for the weekly time of 4-6 hours per week and 6-8 hours per week, followed by 8-12 hours per week as represented in Figure 6.

Figure 5: Students per advisor ratio.

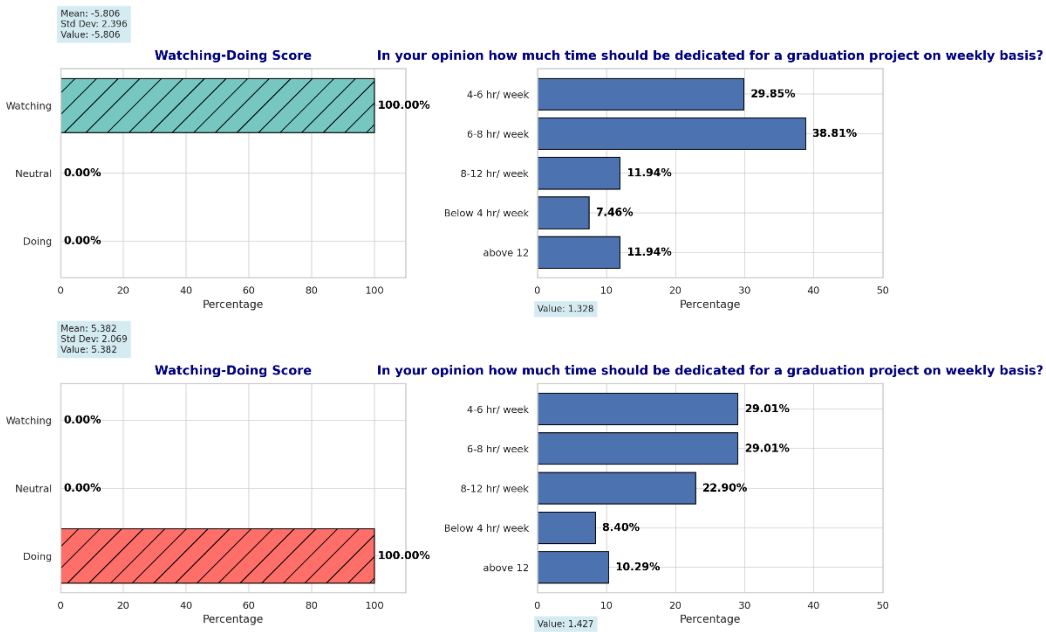


Figure 6: GP hours per week.

- **GP1 or GP2:** In both semesters of the capstone course, the distribution of watching and doing students was approximately equal to 50%. As given in Figure 7, the proportion of 'watchers' was 52% in GP1 and 48% in GP2. This means that in both semesters there was an almost equal number of 'watchers'. Similarly, the case of 'doers' can be explained.

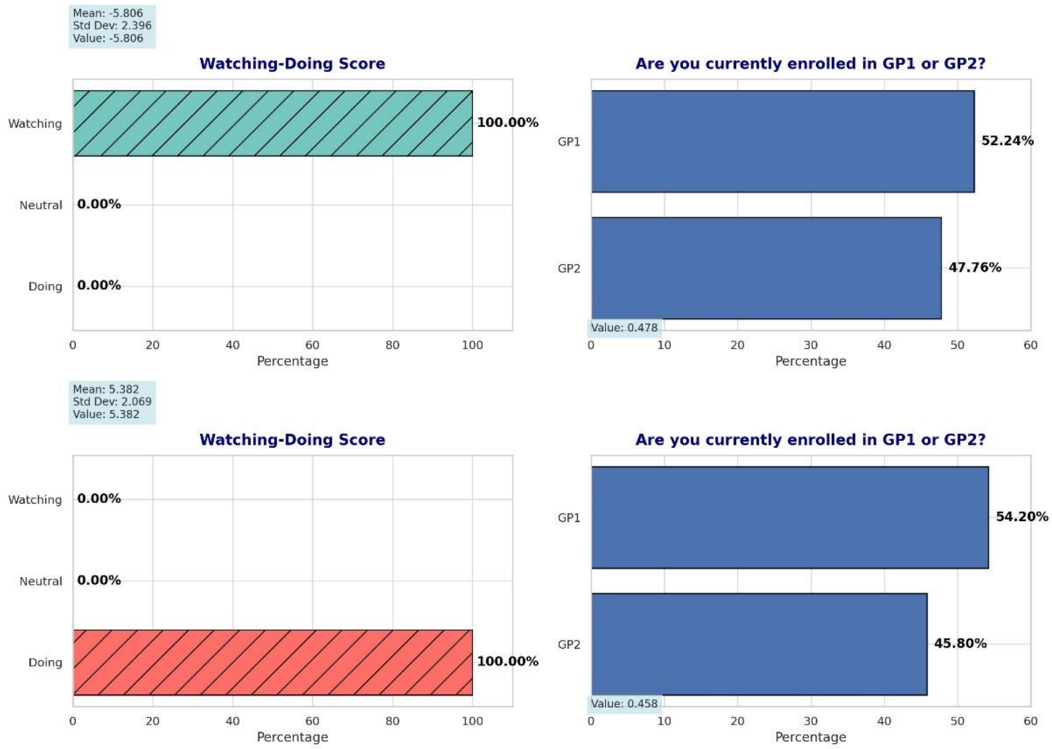
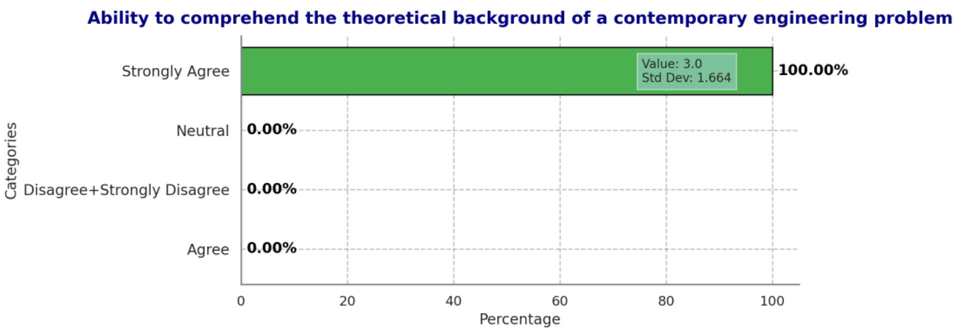


Figure 7: Currently enrolled semester.

4.1.2. Nodes recorded in the Likert scale

In this section, the response of the students recorded on the Likert scale is analysed. Among the total 19 questions analysed in this study, the responses of the four questions that were not recorded on a Likert scale metrics were discussed in the previous section. Hence, the responses related to the remaining 15 questions are analysed in this section. The questions analysed in this section either belonged to questions related to the outcomes of the GP programme or related to the perceptions of the students. In each of these categories the proportion of students who responded as 'Strongly Agree' and 'Disagree + Strongly Disagree' were analysed. Hence, the scenarios were generated concerning the response of the student. An example of the scenario is given in Figure 8.



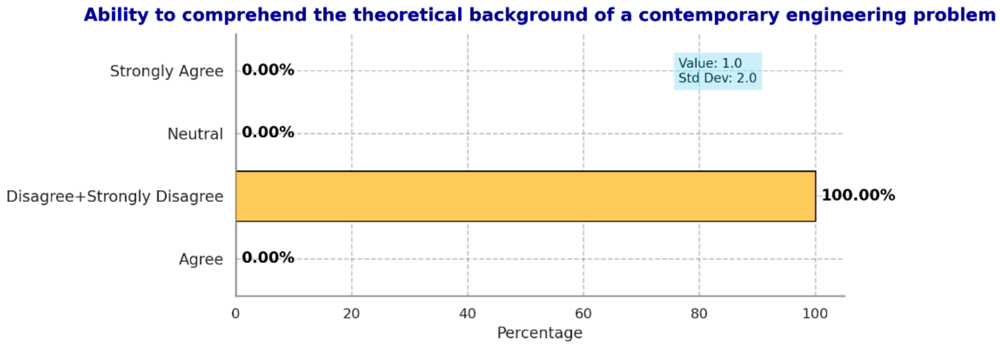
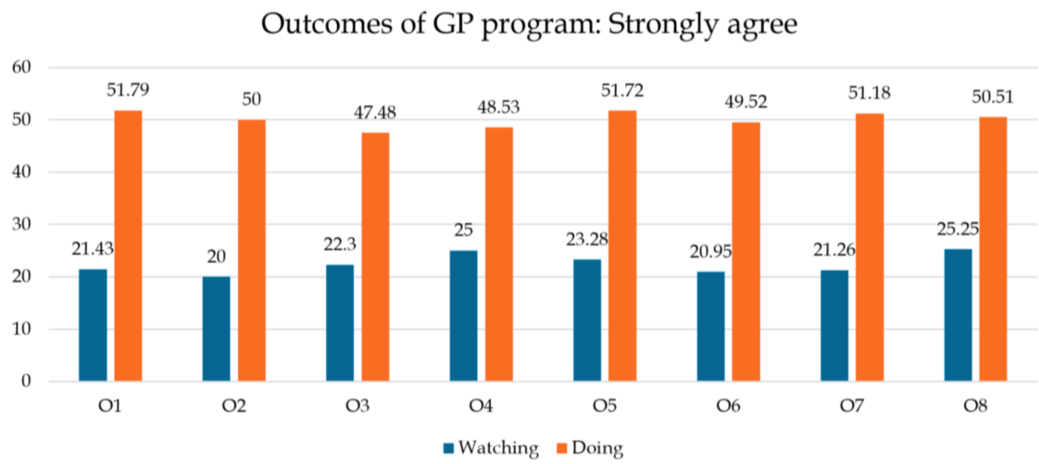
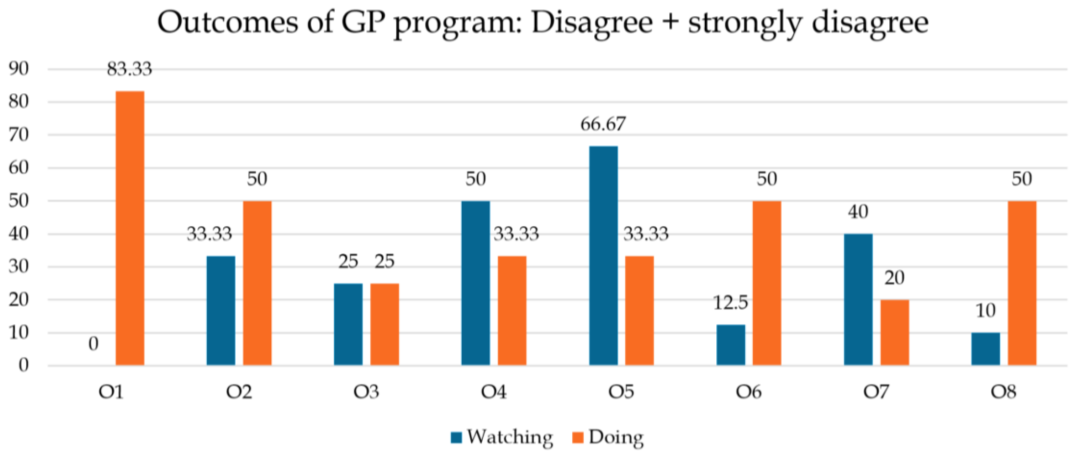


Figure 8: Scenarios considered in the analysis (a)Strongly agree, and (b)Disagree + Strongly disagree

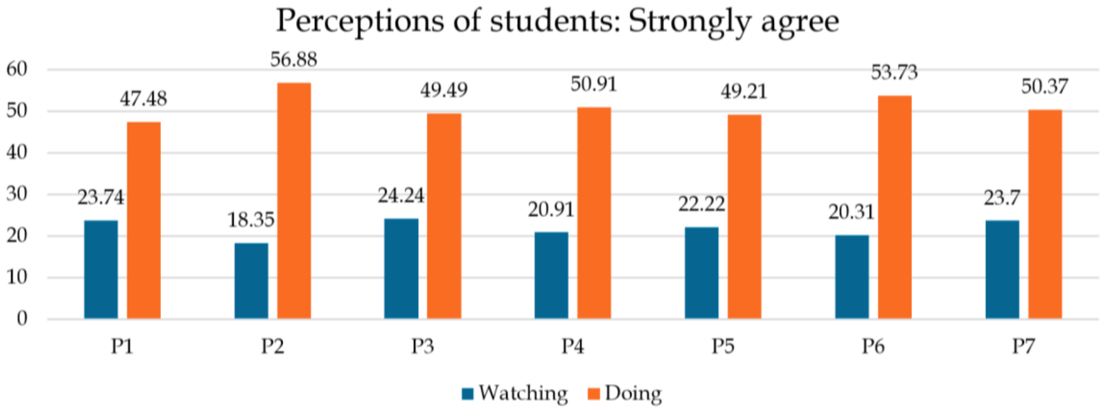
The results of the analysis of each scenario concerning the outcomes of the GP programme and the perceptions of the students are given below in Figure 9 and Table 2. Considering the learning style of the students who strongly agreed with the attainment of the outcomes of the GP programme (Figure 9 (a)) and who strongly agreed that the GP course had a positive impact on their development (Fig 9 (c)), most of them were doing-category students compared to the students who belong to the watching category. On the other hand, analysing the learning style of the students who disagreed with the attainment of the outcomes of the GP programme (Fig 9 (b)) and who disagreed with the positive impact of the GP course on their development (Fig 9 (d)), there was no clear dominance of watching or doing students. It can be noted that in considering each criterion separately, in some cases the percentage of watching students was higher than doing students and vice-versa.



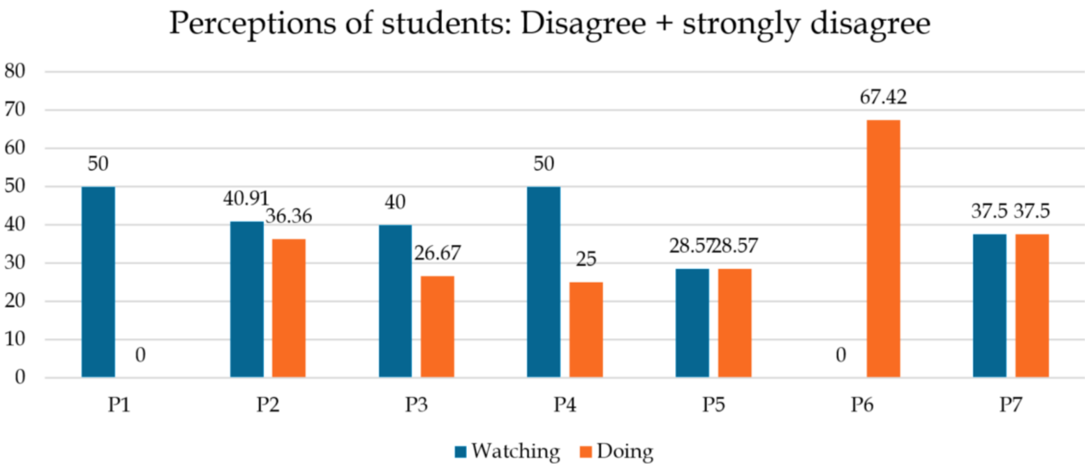
(a)



(b)



(c)



(d)

Figure 9: Analysis of each scenario concerning the outcomes of the GP programme and perceptions of the students.

Table 2: Outcomes and Perceptions

Outcomes		Perceptions	
O1	Ability to comprehend the theoretical background of a contemporary engineering problem.	**P1**	The GP improved my self-regulation and self-learning skills.
O2	Ability to recognise the need of additional knowledge acquisition and integrate this knowledge effectively.	**P2**	Working in groups through the GP was enjoyable.
O3	Ability to communicate effectively through oral and written presentations.	**P3**	The GP prepared me for a professional career and lifelong learning success.
O4	Ability to work collaboratively in a teamwork context.	**P4**	The GP allowed me to apply the knowledge I have gained from the degree courses.
O5	Ability to apply the fundamentals of engineering design practices and procedures including the assessment and evaluation of alternate engineering solutions.	**P5**	The GP improved my communication skills.
O6	Ability to embrace the principles of engineering ethics and recognise social and environmental responsibilities.	**P6**	The GP improved my understanding of the courses related to the project areas.
O7	Ability to develop leadership skills and project management techniques to perform independently in a real work environment.	**P7**	The GP improved my teamwork and collaboration skills.
O8	Ability to develop and conduct appropriate experimentation modelling simulation and/or data analysis using modern engineering tools.		

Even though from the above analyses we inferred that the GP programme is more effective for ‘doing’ category students than ‘watching’ category students, it can be a challenge to analyse the behaviour of students who disagree with the overall success of the GP programme. An example of this can be seen in Figure 9 (a) and Figure 9 (b) for the outcome O1 (Ability to comprehend the theoretical background of a contemporary engineering problem), which explains the challenge in analysing the results obtained in the analysis. It can be noted that among the students who strongly agree approximately 52% belong to the doing category and among the students who strongly disagree approximately 83% are also doing students. This may lead to misinterpretation of the results. The reason for this confusion is the sample size of the responses itself as can be seen in Fig 10. Among the total responses for this question, 41% of the students voted for ‘strongly agree’ while only 2% voted for the disagree option. To avoid the impact of sample size, we decided to calculate an index of the responses provided by the students. The index is calculated by providing a weighting to each response and calculating the exponential value of the responses as explained in the section below.

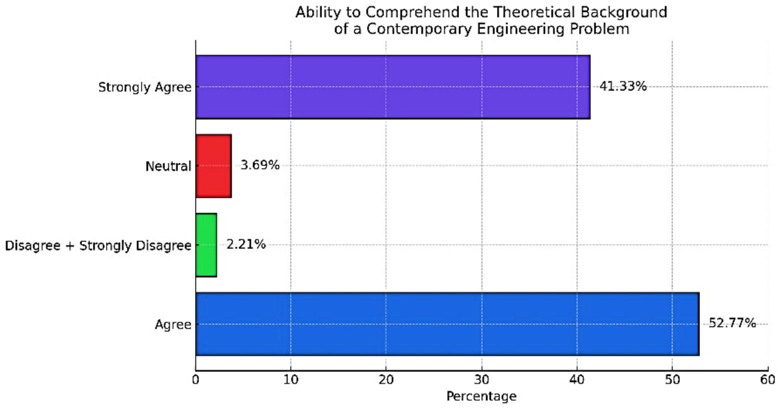


Figure 10: Probability distribution of the total responses of the students towards the outcome O1

4.2. Calculation of response index

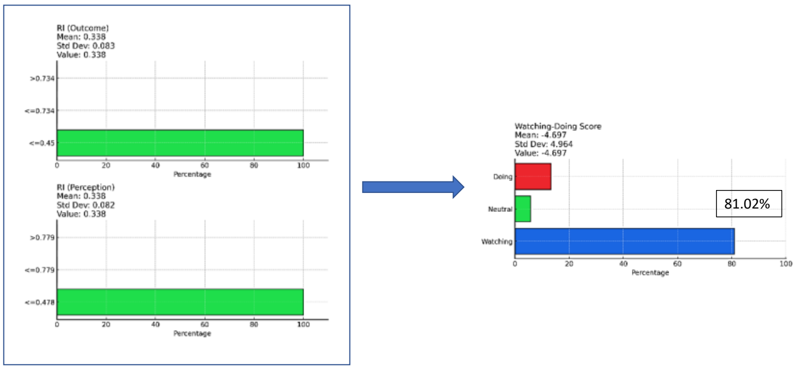
The responses to the questions recorded in the Likert scale range from strongly disagree to strongly agree. While calculating the response index, the aggregation of the states (strongly disagree and disagree) which was assigned during the pre-processing stage is removed. Each of the responses is given a numerical value as given below:

- Strongly disagree – 1
- Disagree – 2
- Neutral – 3
- Agree – 4
- Strongly agree – 5

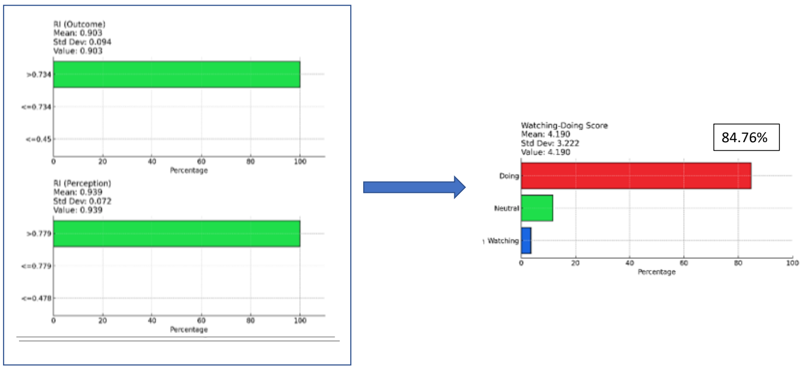
All the responses recorded for the outcomes of the GP course and perceptions of the students are replaced by the numerical value mentioned above. The response index (RI) is calculated separately for the eight questions in the outcomes of the GP course and seven questions on perceptions of students, as given in equation (2).

$$RI = \frac{\sum_{i=1}^{a} e^{n}}{a * e^{5}} \qquad (2)$$

Where a is the number of variables/questions considered; here eight for outcomes of the GP course and 7 for perceptions of students while n is numerical value corresponding to the response of each question ranging from 1 to 5 (1 for strongly disagree and 5 for strongly agree). The relative value of the RI calculated for the outcomes ($RI_{outcome}$) and perceptions ($RI_{perceptions}$) ranges from 0 to 1. We have given the highest weighting to the strongly agree category (which is 5). Hence, if the RI value is closer to 1 implies the responses are toward the agreement category. Similarly, if the RI value is closer to 0 implies that the responses are more tending to the disagreement category. Figure 11 shows the analysis results obtained based on the RI value. The learning style of the students who disagreed with the effectiveness of the GP course were mainly watching-category students with 81.02% as seen in Figure 11 (a). Whereas the learning style of the students who agree with the effectiveness of the GP course falls mainly under the doing- category with 84.76%, according to Figure 11 (b).



(a)



(b)

Figure 11: Analysis based on response index value: (a) Students falling into the disagreement category, and (b) Students falling into the agreement category

5. Discussion

According to the results obtained in this study, the overall effectiveness of the GP programme is agreed by the doing students compared to the watching students. Previous research implies that extrovert students are capable of succeeding in different learning environments due to their strong social skills, whereas introverts tend to be more shy and display reserved behaviour, preferring to gather information through observation and reflection before actively engaging (Alaskar, 2023). Hence, educators need to plan carefully to ensure the complete academic and social development of both extrovert and introvert students. Introverts possess important qualities such as self-efficacy, reflective insight, and consistent inclination (Pascasio et al., 2020). These traits can significantly contribute to the learning process if appropriately nurtured. In research performed among Senior High School students to evaluate the English speaking skills of both extrovert and introvert students through simulation and role-play methods, it was revealed that there is no significant distinction in the speaking proficiencies of both categories concluding that both groups exhibit similar performance using their respective learning strategies (Rofi'i, 2017). This finding emphasises that both extroverted and introverted students can perform equally well when their learning styles are effectively accommodated. The motivation of a student to benefit from a course is influenced by their learning style and personality. Thus, tailoring the instructional methods to cater for the needs of the student and to capture their skills and talents will increase their motivation and engagement (Keshavarz & Hulus, 2019).

The relevance of the BBN approach in this study is significant. BBN provides a robust framework for analysing complex data sets and uncovering probabilistic relationships among different variables, such as learning styles, student perceptions, and course outcomes. This method facilitates a comprehensive understanding of how various elements interact, enabling educators to make data-driven decisions to optimise teaching strategies. By employing BBN, the study effectively captures the learning experiences of the students and provides valuable insights that can inform the development of more tailored and effective educational approaches.

6. Conclusion

In this study, we examined the influence of learning styles of the students on their achievement in a GP programme and their perceptions of various aspects of the GP course. This analysis was conducted using the BBN method. The responses of the students were categorised based on their learning styles: "watching" and "doing," as defined by the 4MAT tool. The "watching" category comprises students who prefer to gather information through observation and analysis before active engagement. Conversely, the "doing" category represents students who learn by actively participating in the learning environment and gaining hands-on experience.

Upon analysing responses from both categories, it was found that a consensus emerged regarding certain aspects. For instance, both groups agreed that a ratio of four students per advisor is optimal for capstone projects. In terms of recommended weekly time commitment, both groups recommended 6-8 hours per week, highlighting the importance of this timeframe for effective engagement in the GP course. Further analysis revealed that the "doing" category generally agreed with the overall effectiveness of the GP programme, whereas the "watching" category displayed a tendency to disagree.

Additionally, analysis based on the response index indicated that the "doing" category seemed to benefit more compared to the "watching" category. Notably, both learning styles possess distinct potentials. Recognising these differences and adapting teaching methods accordingly is crucial to enhance the effectiveness of the GP course. To optimise the capstone project experience, instructors should employ strategies catering for both learning styles. This includes incorporating a mix of individual and group assignments, offering various presentation formats, and providing diverse interaction options.

These findings underscore the importance of recognising and adapting to diverse learning styles in engineering education. Tailoring instructional methods to these styles can significantly enhance the learning experience and outcomes of capstone projects. However, although the study involved 271 participants from diverse streams, the sample size might not be sufficiently large to generalise the findings to all engineering students or other academic disciplines even to students in other universities. Additionally, the data was collected at a single point in time. This limits the ability to draw conclusions about causality or the long-term effects of learning styles on the outcomes of the GP programme. By acknowledging these limitations, future research can aim to address these gaps and further validate the findings through more comprehensive and diverse methodologies.

Future research should continue to explore innovative teaching strategies that balance mentorship and independence, further examining how different learning styles can be effectively accommodated. Additionally, longitudinal studies could provide deeper insights into the long-term impacts of these tailored educational strategies on professional success post-graduation. In conclusion, creating a balanced learning environment that addresses diverse student requirements is crucial for the success of capstone courses. By aligning teaching methods with the varied learning styles of students, educators can significantly improve the effectiveness of the GP programme, ultimately producing better-prepared graduates.

7. References

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