CDIO-BASED APPROACH: INTEGRATED LEARNING EXPERIENCE IN TIME SERIES MODULE

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ABSTRACT

This paper presents an integrated learning approach implemented in the Time Series module designed for Data Science students at ESPRIT School of Engineering. Crafted within the CDIO framework, the approach consists of designing and implementing end-to-end solutions for Time Series forecasting at advanced level. It addresses real-world challenges while prioritizing additional learning objectives that promote the development of personal and interpersonal skills, including collaboration, critical thinking, ethical awareness, and other relevant abilities. To ensure the grasp of theoretical and practical aspects of Time Series fundamentals, students are divided into working groups to actively engage them in their learning process through the integration of three key elements adhering to the objectives of an Integrated Learning Experience; the adoption of the Golden Circle framework, the utilization of the CRISP-DM work methodology, and the consideration of the 17 Sustainable Development Goals (SDGs). The approach delivery consists of a presentation that emphasizes all project phases. Assessment tools are designed to evaluate the methodology of work, the delivered cognitive output in addition to personal and interpersonal skills. The validation of the approach is equally reliant on students' feedback as a valuable tool. Formative and Summative evaluations of this approach have shown promising results, with students exhibiting increased confidence, competence and awareness in applying mathematical concepts to real-world scenarios. All things considered, this approach is applied to one class of students among three, and comparing final exam grades revealed an improved cognitive learning experience compared to the other two classes.

KEYWORDS

CDIO framework, Integrated Learning, Personal and interpersonal skills, Sustainable Development Goals, Time Series, Standards: 1, 2, 3, 5, 7, 8, 11

INTRODUCTION

Integrated education has gained significant attention in higher education, over the last decades, as universities recognize its potential to prepare learners for the complex challenges of the 21st century by integrating knowledge, skills, and insights from multiple disciplines (Clark, 2023; Klein, 1990; Tuselim, Muhammad, & Mai, 2020). Indeed, by fostering a more holistic and interdisciplinary outlook, integrated education helps learners become active and responsible citizens in a rapidly changing world. Several techniques and frameworks have been developed, in that way, to promote problem-solving, critical thinking, and practical learning in various fields such as, Problem/Project-Based Learning (PBL) (Woods, 2003; Bender, 2012), ChallengeBased Learning (CBL) (Johnson, Smith, Smythe, & Varon, 2009), and Conceive-DesignImplement-Operate (CDIO) framework (Crawley, 2002), to name a few. Although they share some similarities, each technique and framework has its unique features and has been implemented in different domains such as computer science (Cheung, Cohen, Lo & Elia, 2011), medicine (Barrows, 1996), civil engineering (Krogsbøll et al., 2011), etc. From the same perspective, this paper introduces an integrated learning approach implemented within the CDIO framework in a challenging subject for students: Mathematics. More precisely, the approach involves an enriched Design-Implement experience applied to the Time Series module designed for Data Science students at ESPRIT School of Engineering in Tunisia. As a matter of fact, since 2011, ESPRIT incorporates a variety of cutting-edge learning methods in its curriculum, including PBL, active learning, and more (Louati, Alaya, Khodjet El Khil, Aissa, & Bettaieb, 2016; Sifi & Alouane, 2016). While the Time Series module is already crafted with consideration for certain CDIO standards, it does not fully adhere to them in its current form. In fact, its foundation is built on fundamental mathematical concepts, complemented by practical hands-on applications to effectively analyze, model, and forecast Time Series data, where the continuous assessment and final evaluation focus mainly on cognitive acquisition. In view of the significance of Time Series analysis in diverse sectors like economics, finance, and climate science, etc, and the acknowledgement of the intricacies inherent in the underlying theory, the proposed approach provides improvements at three different levels: 1) Enhancing the cognitive acquisition for a better understanding of technical aspect of Time Series, and its significance in the field of data science. 2) Developing personal and interpersonal skills in order to enable students to comprehend the problem to be solved and the working environment in all its facets and aspects, as well as preparing them for professional engineering practice. 3) Incorporating the United Nations' Sustainable Development Goals (SDGs) (Pedersen, 2018) to encourage students to recognize their global role and foster responsibility for addressing worldwide challenges. The presented integrated approach impacts the assessment methodology rather than the teaching pedagogy. Indeed, in contrast to classical assessment, students are tasked with designing and implementing comprehensive solutions for Time Series forecasting at an advanced level. This involves delving into real-life problems and comprehending them from various perspectives, including theoretical, practical, societal, environmental aspects, and more. Divided into working groups, students were actively engaged in the learning process through the integration of three key elements adhering to the objectives of an Integrated Learning Experience. First, the adoption of the Golden Circle framework (Sinek, 2011) addresses the fundamental questions: Why are we doing this? How do we do it? and What are we doing?

It promotes effective communication and student interactions. Likewise, it cultivates creativity, critical thinking, and problem-solving skills and fosters a sense of social responsibility and ethical considerations in developing the final solution. Second, the utilization of the Cross-Industry Standard Process for Data Mining (CRISP-DM) work methodology (Wirth & Hipp, 2000), widely used in Data Science, structures the project from understanding business

objectives and data exploration to modelling evaluation and deployment. Last but not least, the consideration of the 17 SDGs, where the mapping with CDIO standards is highlighted in (Rosén et al., 2019), empowers students as responsible global citizens to align with evolving societal and professional expectations. The new pedagogical approach conforms to CDIO standards 1, 2, 3, 5, 7, 8, and 11, ensuring an enriched integrated learning experience for the Time Series module. The approach delivery consisted of a presentation that accentuates all project phases while spotlighting the integration of the three key elements: the Golden Circle framework, the CRISP-DM work methodology, and the SDGs. Furthermore, assessment tools were designed to evaluate the methodology of work, the delivered cognitive output in addition to personal and interpersonal skills. The results observed during presentations were highly satisfactory, demonstrating mastery of the technical aspect of Time Series, self-confidence, and a thorough exploration of all facets of the studied problem, coupled with an awareness of the SDGs at hand. For a more in-depth study of the reliability of the proposed approach on the cognitive level, the approach was exclusively implemented in one class of students among three. A comparison of results was conducted using the grades from a common final exam across all three classes. The statistical analysis revealed an enhanced cognitive learning experience for the class where the approach was applied, compared to the other two classes. The validation of the approach equally depended on students' feedback as a valuable tool. A questionnaire consisting of 15 questions was filled out by students to collect their opinions on the approach. Upon analyzing the results, it was observed that students generally perceived the approach to be effective and valuable, enhancing their understanding of the material. Furthermore, they reported being more engaged in the learning process. Through the questionnaire, students provided suggestions for improvement that we take into consideration in the upcoming iterations. The remainder of this paper includes a presentation of the current Time Series module, an explanation of the proposed integrated learning approach and its alignment with CDIO standards, an illustration and discussion of obtained results, and conclusions drawn in the final section.

TIME SERIES MODULE

The Time Series module is intended for students in the 4th year of the computer engineering program at ESPRIT, including the Data Science and Business Intelligence Specializations. It corresponds to 2 ECTS credits and lasts for 30 hours which spread over 10 weeks. As mentioned earlier, the Time Series module has been already structured according to the CDIO framework but with insufficient focus on the cultivation of personal and interpersonal skills. It is delivered in the form of an integrated course, featuring lectures that expound on theoretical foundations grounded in mathematical concepts, with a particular emphasis on practical applications. Additionally, it is complemented by tutorials for hands-on practice. The module comprises a series of steps and tests that must be performed to successfully achieve Time Series forecasting. Consequently, the primary goal of the Time Series module is to instruct students in the analysis, modeling, and prediction of Time Series. The assessment for the Time Series module is summative. The final grade that awarded to the student is composed of 20% from the continuous assessment and 80% from the final exam grade. The final exam is administered in the form of a written test that assesses the learning outcomes defined in the module syllabus using Bloom's taxonomy. On the other hand, the continuous assessment takes the form of a project, primarily evaluating practical learning outcomes. As the pedagogical approach presented in this paper pertains to the assessment of the module, we provide more details on its current methodology in what follows. Indeed, towards the end of the module, the students, already organized into teams (typically composed of 5 to 7 students), are provided with two Time Series that present varying levels of difficulty in analysis. Each

team is tasked with navigating through all stages of Time Series analysis to achieve successful forecasting. During the final session, each group presents its analysis via an executable deliverable for a purely technical validation of the accomplished work.

PROPOSED INTEGRATED LEARNING APPROACH

Clearly, the novel approach appears to focus solely on altering the continuous assessment method. However, underlying this change is the intention to cultivate new skills in students, which involves enhancing their understanding of technical concepts, refining the quality of their work, and developing personal and interpersonal skills, all while fostering an awareness of SDGs. Indeed, instead of receiving the data (Time Series) at the end of the module, team members receive it right from the beginning with the aim of working on it in parallel as the course progresses. Each time a step in the Time Series analysis is covered in class, it is immediately applied to the provided data. Throughout the project, students are tasked with:

1. Work in teams: It offers numerous advantages for students, including the development of essential skills such as problem solving and delegation, enhanced learning, improved communication, increased participation, deepening of knowledge, and social support.

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2. Development of an end-to-end solution for the provided Time Series forecasting: By engaging in the complete process, students gain practical insights into the complexities of real-world problem-solving, while applying theoretical knowledge to tangible scenarios. This approach fosters a deeper understanding of the subject matter, encourages critical thinking, and cultivates problem-solving skills. Additionally, it promotes a holistic perspective by integrating theoretical concepts with practical applications, contributing to a more comprehensive and meaningful learning experience.

3. Integration of the Golden Circle framework to answer the three questions “What?” “Why?” and “How?”. It brings clarity to the problem’s purpose (What?), motivates intrinsically (Why?), and guides strategic problem-solving (How?). This enhances the learning experience and fosters the development of personal and interpersonal skills among students. Effective communication and collaboration in conveying the "What," "Why," and "How" contribute to their comprehensive skill set.

4. Implementation of the CRISP-DM methodology: It supports a holistic study of the underlying problem, fostering a deep understanding of the entire data science project. This approach ensures a systematic and thorough examination, contributing to a more insightful analysis and solution development. As well, it promotes systematic problem-solving, teamwork, and communication skills, leading to a comprehensive educational experience.

5. Identification of the associated SDGs with the studied problem: It fosters a holistic and socially responsible approach to data analysis. It adds a layer of ethical consideration and aligns technical solutions with broader global objectives. By examining the involved SDGs in the Time Series project, the analysis gains relevance to societal challenges, contributing to responsible and purpose-driven data science.

This integration encourages students to recognize the broader implications of their work and promotes a mindset of ethical and sustainable problem-solving.

6. Summarizing all previous points in an English (foreign language) oral presentation during the last session to evaluate the work performed. Unlike traditional evaluation solely focused on cognitive acquisition, this new approach considers all aforementioned points.

With the new approach, it becomes evident that the Time Series module aligns more closely with the CDIO standards outlined below, demonstrating a stronger adherence to their principles.

Standard 1: The new approach consists of a Design-Implement experience that focus on the development of personal and interpersonal skills.

Standard 2: The new approach adds new learning outcomes related to personal and interpersonal skills such as engineering reasoning, awareness of professional ethics, etc.

Standard 3: With the new approach, the curriculum is crafted to feature mutually reinforcing disciplinary courses, with a clear strategy for blending personal and interpersonal skills.

Standard 5: Students design and implement an end-to-end solution at an advanced level by integrating personal and interpersonal skills.

Standard 7: The new approach enables a holistic exploration of the problem within its complete environment, addressing technical aspects, SDGs, environmental considerations, and more. This integration of theory and practice, through hands-on experiences, allows students to delve into various facets of the problem.

Standard 8: Students were engaged actively in discussions, collaboration, thinking, problem-solving, and hands-on activities, shifting away from passive information transmission.

Standard 11: The assessment involves a team presentation that emphasizes various skills, including disciplinary, personal, and interpersonal competencies.

RESULTS AND DISCUSSIONS

Exam grades analysis

Using identical course materials and teaching pedagogy across 3 randomly selected classes of students; Class 1, Class 2, and Class 3, out of 9 in the Data Science specialization, the new integrated experience was implemented exclusively in Class 1. To assess its impact on achieving the learning outcomes, described in the Time Series module syllabus, we conducted a comparison using the final exam results. This exam was common to all 9 classes of students and administered during the main exam session in May 2023. The performance outcomes of students are illustrated in Table 1 and Figure 1, where best results are associated with the Class 1. Indeed, the Table 1 shows that the greater grades mean 10.86 is obtained for Class1 compared to 9.83 and 10.18 for Class2 and Class3, respectively. In addition, the highest estimate median 11.25 is observed with the Class1. For that same value 11.25, the percentage of grades above this latter is 55,55% for Class1, compared to 28.13% and 36.67% for Class2 and Class3, respectively. A noteworthy observation, through Figure 1 where results are

represented in percentage, is the prevalence of scores between 10 and 15 (indicating that the module is validated), constituting approximately 67% in Class1 compared to around 47% and 57% in Class2 and Class3, respectively. Upon closer examination of these variations and their implications, it becomes clear that the integrated teaching method positively influenced students' performance and enhanced the acquisition of learning outcomes related to disciplinary knowledge.

Table 1. Statistics of obtained grades for the three classes, Where N_s and N_{pe} indicates the number of students and the number of students that passed the final exam, respectively

	N_{pe}	N_s	mean	standard deviation	minimum	median	maximum
Class 1	27	29	10.86	2.50	5.25	11.25	15
Class 2	32	32	9.83	2.25	5.75	9.75	14.25
Class 3	30	31	10.18	2.40	4.75	10.63	14.25

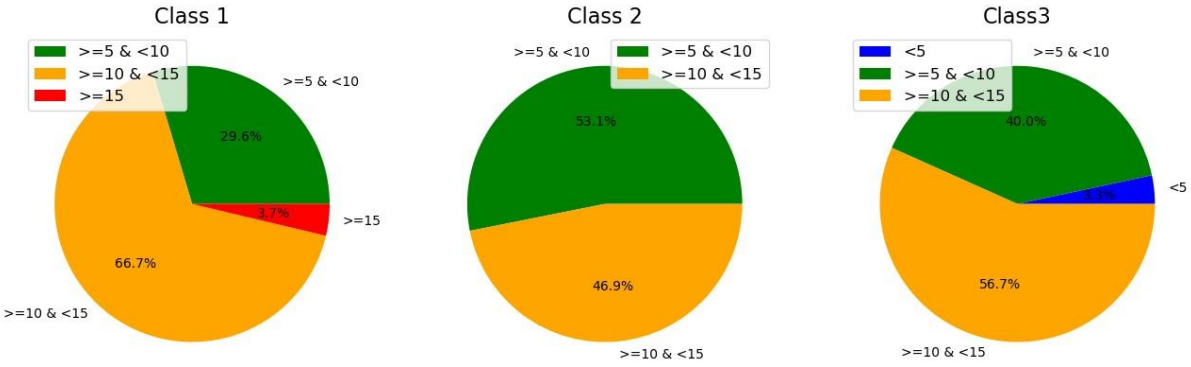

Figure 1. The three classes' grades categorized into 4 groups: strictly below 5 (in blue), between 5 and 10 strictly (in green), between 10 and 15 strictly (in orange), and above 15 (in red)

Students feedback analysis

In order to gather additional information about the integrated approach, we developed a questionnaire consisting of the following 15 questions (**Q1** to **Q15**), in a variety of formats, including open-ended, Likert-scale and multiple-choice questions. These questions were designed to elicit students' views on 5 mains aspects: Disciplinary knowledge (**Q1**, **Q2**, and **Q15**), Engineering skills (**Q3**, **Q4**, **Q8**, and **Q6**), SDGs (**Q7**, and **Q5**), Integrated learning approach (**Q9**, **Q10**, **Q13**, and **Q11**), and Overall Experience (**Q12**, and **Q14**).

Q1: To what extent did the integrated approach contribute to your understanding of the technical aspects in Time Series?

Q2: How well did the integration of end-to-end solutions for Time Series forecasting contribute to the understanding of the module objectives?

Q3: How effective was the Golden Circle Framework in deepening your overall understanding of the project?

Q4: To what extent do you think this approach has contributed to the development of your interpersonal skills, (such as communication, leadership, teamwork. . .)?

Q5: Did the integration of the SDGs in the Times Series module raise your awareness towards the principles of sustainability and society?

Q6: Was the integration of CRISP-DM methodology helpful in organizing and managing your project properly?

Q7: How do you rate the overall integration of SDGs in the time series module?

Q8: To what extent do you think this approach has contributed to the development of your personal skills (e.g., critical thinking, problem solving, work ethics. . .)?

Q9: How efficient is this approach in learning Time Series?

Q10: How satisfied are you with the integrated learning approach in teaching Time Series?

Q11: To what extent do you consider the teacher's supervision necessary for the task at hand during each session?

Q12: How do you rate your overall learning experience in the Time Series module?

Q13: Were there any challenges with this integrated learning approach?

Q14: Do you have any recommendations related to the integrated learning approach in Times Series teaching?

Q15: What factors contributed to improving your understanding of the various technical aspects covered in the module? Tick all that apply. 1) Integration of the Golden Circle: The What? Why? and How? method. 2) Use of the CRISP-DM methodology to conduct the project. 3) Teamwork: discussions and interactions. 4) Integration of the SDGs : being aware of professional and societal challenges. 5) Development of an end-to-end solution. 6) Other.

Over 29 students of Class1, 25 ones filled out the questionnaire under google forms. In figure 2, we represent the results of the first 12 questions given on a 5-point likert scale, where a rating of 1 signifies the lowest evaluation, while a rating of 5 indicates the highest evaluation. Throughout this figure, we can easily see that orange and red colors are dominating which are associated to answers 4 and 5, respectively. These results confirm the overall satisfaction of students regarding the new approach. Especially, with the implementation of an end-to-end solution for Time Series forecasting, where students showed a great appreciation in Figure 2, Q2 with 88% of satisfaction. These results suggest that the holistic approach of learning has positively impacted students' technical understanding of the subject, fostering the development of personal and interpersonal skills while fully grasping the underlying studied problem. Additionally, the majority of responses for most questions have an average value greater than 4, excluding questions **Q4**, **Q5**, and **Q7**. These questions focus on developing interpersonal skills and integrating SDGs, where the average values are 3.8, 3.84, and 3.68, respectively. This suggests that some students may not yet fully appreciate their importance. This issue

becomes even clearer when examining students' responses to **Q15**, given by Figure 3, where students indicate the success factors of the new approach, chosen from a predetermined list of factors (see **Q15**), with the possibility of adding others. Key components of the integrated approach were mentioned by students with percentages above 64%, except for the integration of SDGs, which is cited by just 48% of students. With full knowledge, it might be beneficial to emphasize the importance of SDGs further in upcoming iterations.

To empower students to share their critiques, we incorporated two open-ended questions in the questionnaire: **Q13** and **Q14**. Besides recommendations that indicate a general consensus among students who found the integrated approach effective, different challenges has been mentioned, such as time constraints and preferences for quantity over quality, indicating potential areas for improvement. Addressing them could further enhance the overall approach's effectiveness. Another drawback that has been well highlighted by **Q11** concerns the necessity of the teacher's Supervision. Some students may feel the need for more guidance, emphasizing the importance of flexibility in teaching approaches to cater to individual needs.

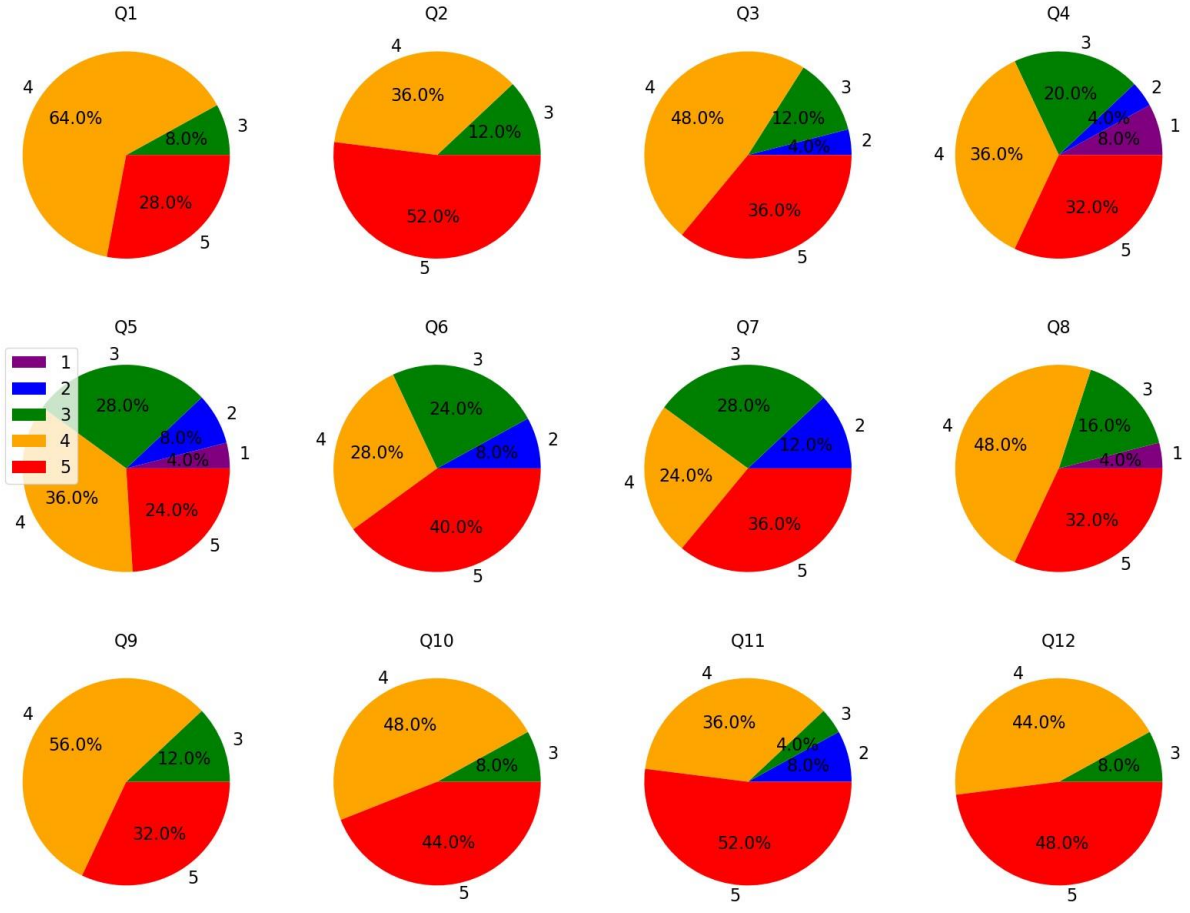

Figure 2. The students' feedback

CONCLUSIONS

This paper introduces a robust pedagogical approach implemented within the Time Series module for Data Science students at ESPRIT School of Engineering. Rooted in the CDIO

framework, the approach seamlessly integrates disciplinary knowledge acquisition with the cultivation of personal and interpersonal skills.

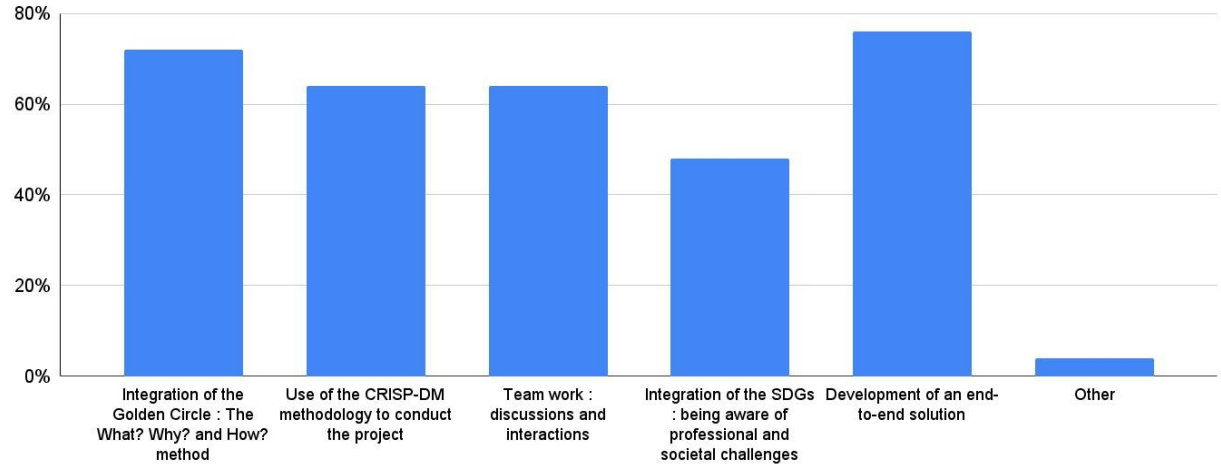

Figure 3. Students' responses to Question 15

Validation supported by students' feedback affirms its efficacy. Comparative analysis reveals improved cognitive learning experiences, suggesting broader application in educational contexts. As industries increasingly value not only technical expertise but also collaborative abilities and ethical considerations, this approach prepares students for a well-rounded professional journey. Looking ahead, this pedagogical approach holds promising perspectives for shaping the education landscape in the context of Time Series analysis and beyond. Its adaptability to different classes, subjects, or institutions holds transformative potential in how students engage with and apply their knowledge. As the education landscape evolves, this approach serves as a beacon for incorporating not just technical proficiency but a holistic set of skills that will empower students to thrive in the ever-changing world of Data Science and beyond.

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