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Design and Implementation of a Badge Architecture to Motivate Students' Excellence in an Engineering Calculus Course

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Byron Haroldo Linares Roman

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1. Introduction

It is well known that a significant number of freshmen engineering students often face a lack of motivation while studying calculus due to different factors that can be discouraging and affect their performance not only in this course but also in their overall university experience. A limited mathematical background coupled with the theoretical and abstract nature of calculus may lead some students to feel overwhelmed and demotivated [1]. Furthermore, most first-year engineering students aim to solve real-world problems from their first days of class; however, they find themselves loaded with theoretical courses that seem distant from engineering applications at the early stage of their academic journey. Last but not least, test scores commonly assess student performance, but they do not provide a complete measure of students' interests and their level of engagement in the class [2]. Several approaches have been proposed in the literature to mitigate this problem. Among them, in this paper, we are interested in the use of *digital badges* to enhance students' motivation, develop long-lasting enthusiasm for mastering calculus, and provide an alternative way to showcase their learning progress [3].

According to [4], digital badges are essentially virtual artifacts granted to individuals as micro-credentials to record events, such as achievements, competencies, or mastery of skills, which could involve completing a course, participating in professional development, or finishing a training program. In other words, digital badges are similar to medals earned in the physical world, as they offer visual recognition of a person's accomplishments. The introduction of badges granted to users upon completing specific tasks was predominantly centered on gaming. The widespread and successful integration of badges into online games occurred in 2005 with the addition of "achievements" to the Xbox Live platform [5]. In engineering education, the inclination towards achievement-oriented rewards was influenced mainly by the widespread participation in gaming culture [6]. In recent years, different digital badge architectures have been introduced in this context as a valuable tool for motivating students to engage with the course content and strive for exceptional grades in midterms and final evaluations, among many others [6]. Actively involved students continually evaluate their progress, reinforce their knowledge, and adapt their strategies for future improvement [7]. Besides, badge architectures play a crucial role in learning management by providing students with a clear understanding of the instructors' expectations. Through badges, students gain awareness of the specific criteria and goals set by their instructors. These architectures organize knowledge by creating conceptual maps and temporal frames, enabling students to navigate their learning journey more effectively [6]. Thus, the incorporation of digital badges in engineering education can be seen as an opportunity not only to intrinsically motivate students but also to enhance their learning experience by letting them visually track their progress and completion status in a course [6].

Based on the Framework for Successful Badge Program Implementation (FSBPI) presented in [8], in this paper, we introduce a novel digital badge architecture for a second calculus course for engineering students. The FSBPI provides a series of recommendations within three main categories: *(i)* badge instructional design, *(ii)* badge system platform, and *(iii)* badge program implementation. The main objective of this study is to present all details regarding the design, implementation, and validation of our calculus badge architecture and how this framework helped us achieve the desired results. The rest of this paper is organized as follows. Section 2 presents a quick overview of the FSBPI, highlighting its primary objective, structure, and main features. The main results regarding the implementation of the proposed calculus badge architecture are summarized in Section 3. Finally, in Section 4, we draw some conclusions and present our future work.

2. A Quick Overview of the FSBPI

In this section, we summarize the principal recommendations for designing a badge architecture encapsulated within the FSBPI. Such a framework strategically categorizes recommendations into three distinct categories derived from the extensive analysis of badge programs implemented in different higher education institutions. Those recommendations are specially oriented towards adding purpose and value to badges. In particular, the FSBPI encompasses the following domains:

- *Badge Instructional Design:* this category provides a series of recommendations related exclusively to the instructional elements of badges. More specifically, those suggestions include establishing clear criteria that students must meet to earn a badge, and the alignment of badges with the course learning objectives or competencies. In other words, according to the FSBPI, the incorporation of badges should not be arbitrary; rather, their adoption should be purposeful, ensuring that they serve as an effective means to attain specific learning objectives. This category of the FSBPI also emphasizes that learning activities associated with badges should be substantial and directly connected to tangible evidence, thus incorporating rigor into the badge architecture. Furthermore, this FSBPI category advocates for embedding data within badges (metadata), i.e. additional information providing details about the achievements or skills represented by the badges [9].

- *Badge System Platform:* this category focuses on ensuring the manageability and sustainability of the badge platform. When implementing a badge architecture for the first time, the FSBPI advises opting for an open-source badge system to minimize the faculty workload and address potential usability challenges. Linking the badge system seamlessly with the Learning Management System (LMS) further streamlines faculty responsibilities and, at the same time, facilitates its use. Clearly, implementing a badge architecture is not straightforward, an effective strategy to alleviate the additional workload includes considering the affordances of technology available and outsourcing specific tasks to students and other faculty with expertise in areas such as graphic design, technology, and content, among others.

- *Badge Program Implementation:* this category guides the effective launch and continuous assessment of a badge architecture. According to the FSBPI, when incorporating badges into a course, emphasizing its purpose and value is crucial. Thus, establishing how badges serve as a solution to an instructional or curricular problem must be communicated to faculty and students from the beginning of the implementation process. Additionally, the FSBPI suggests that demonstrating to faculty and students how badges can be shared externally may foster a broader understanding of their value. Finally, to guarantee the success, sustainability, and potential scalability of the badge architecture, the FSBPI recommends designing and incorporating a comprehensive evaluation and a revision plan. This plan must include instructors and teaching assistants (TA) continuous training to ensure grading consistency across multiple course sections and, at the same time, reinforce the program's overall effectiveness.

These three categories collectively form a cohesive blueprint to guide the successful integration of badges into engineering courses, thus providing valuable insights (based on real cases) for faculty interested in a new implementation. We refer the interested reader to [8] for more details regarding the FSBPI. In the next section, we introduced our badge architecture for our second calculus course based upon the strategies and recommendations made by the FSBPI along with other inputs from the related literature, see e.g. [10, 11].

3. Proposed Badge Architecture for a Calculus Course

a. Our Calculus Course

According to [6], badge architectures serve as a visually appealing translation of the course syllabus, naturally aligning the course content with the objectives and competencies to develop in the students. In other words, badge architectures may act as a valuable tool for turning the formal course syllabus into a creative and fun way for students to engage with and help understand the course structure. As a result, we start this section by briefly describing the content and objectives of our second mathematics course for freshmen engineering students, called for shortness MATH 202.

MATH 202 continues with the study of calculus for functions of a single real variable. More precisely, MATH 202 reviews and reinforces the fundamental concepts of differential calculus, but it focuses primarily on integral calculus. MATH 202 is divided into the following three units.

- *Unit 1 - The Derivative and its Applications:* starts with a quick recap of the concept of derivative and the differentiation rules. This unit emphasizes the study of different applications of differential calculus including related rates, linear approximations, differentials, graphing, and optimization problems, among others.
- *Unit 2 - The Definite Integral and Techniques of Integration:* introduces the concept of definite integral through the area problem and presents the Fundamental Theorem of Calculus. The rest of the unit is devoted to the study of integration techniques.
- *Unit 3 - Applications of Integration:* in this unit, integral calculus concepts are applied to solve diverse problems such as areas between curves, volumes, average value of a function, arc length, area of a surface of revolution, work, and hydrostatic force, among others.

It is important to highlight that each course unit is covered in five weeks. At the end of units 1 and 2, a midterm exam is administered to evaluate the student's progress. Similarly, a comprehensive final exam takes place at the end of unit 3. This timeline is relevant because, as explained in the following section, it is used to trigger the digital badges.

MATH 202 follows the Active Topic Centered Learning (ATCL) methodology introduced in [12], thus each course unit is subdivided into *topics*. A *topic* is the smallest component of a course unit and is indivisible into subtopics. The ATCL requires the development of each topic through a short lecture, a corresponding worksheet, and a mini-quiz. As a result, in MATH 202, students are evaluated through a combination of assignments including: 28 worksheets, 28 mini-quizzes, two mini-application projects (MAP), two midterms, and one final exam. All of these assignments emphasize three aspects: theoretical understanding, operational skills, and practical application of calculus principles. Therefore, upon the completion of MATH 202, we expect students to have a solid understanding of both differential and integral calculus concepts, enabling them to apply the provided tools in the solution of problems in science and engineering. Additionally, mathematics courses help students develop skills such as analytical reasoning, accuracy, interpretation, patience, perseverance, and critical thinking, among many other skills.

In the following subsections, we explore the design, implementation, and validation process of a badge architecture for MATH 202, highlighting how adherence to the FSBPI recommendations helped us achieve the intended objectives.

b. Badge Instructional Design

One of the main recommendations of this category of the FSBPI is to establish the purpose of introducing badges into a course. As mentioned above, the main objective of developing a badge architecture for MATH 202 is to seek a potential strategy to boost students' motivation and, at the same time, guide their learning process accurately. In other words, our goal is to motivate students to be more engaged with the course content and encourage them to aim for top grades. According to [6], based on gamification principles, badge architectures are effective pedagogical tools that make the educational experience more enjoyable by aligning with the playful nature of video games and directing students' attention toward meaningful learning outcomes, thus blurring the boundary between learning and playing.

The FSBPI suggests that badges should be tied directly to the course learning objectives. The student's scores on well-designed assignments are a way to measure the accomplishment of a learning objective. Consequently, in the design of our badge architecture for MATH 202, we used the scores from different course assignments, including mini-quizzes, worksheets, midterm evaluations, projects, and the final exam, as evidence of accomplishment. This approach led us to divide our badge architecture into the following five categories: *(i)* Mini-Quizzes, *(ii)* Worksheets, *(iii)* Exams, *(iv)* MAPs, and *(v)* Final Scores. Tables 1 to 5 provide a detailed description of each badge category, along with its embedded metadata [9], as required by the FSBPI. The rest of this section is dedicated to presenting the details of the referred badge categories.

The badges in the Mini-Quizzes category (see Table 1) evaluate the students' daily work as these short exams are conducted almost twice a week. As stated in Table 1, these badges are awarded to students who achieve an average score equal to or greater than 61 out of 100 points in all the mini-quizzes corresponding to a particular set of topics. The score of 61 points corresponds to the university promotion grade. The binary nature of these badges transmits a clear message: if a student holds the badge, it demonstrates proficiency in the topics evaluated; conversely, the absence of the badge indicates that the student needs further comprehension of that particular subject. Even more, the mini-quizzes badges are conferred before each midterm and the final exam, allowing students to use them for self-evaluation and guide their exam preparation as they are linked to specific course learning objectives. On the other hand, the data obtained from this badge category let instructors assess the overall understanding of the group, identify specific areas of opportunity, and tailor instructional strategies accordingly, thus enhancing the student's learning experience. Finally, notice that, despite the course being based on the ATCL methodology, we include 18 badges, do not including a badge for *each* course topic (28 in total) but for *groups* of topics, so that the number of badges remains manageable and not overwhelming for both students and faculty.

Category	Badge Name	Levels	Criterion for Earning the Badge	The badge is awarded when:
Mini-Quizzes	Leibniz in Process - 1	Gold	It is awarded for achieving an average score above 61 points in the mini-quizzes related to *differentiation rules*.	All the mini-quizzes scores are available.
	Leibniz in Process - 2	Gold	It is awarded for achieving an average score above 61 points in the mini-quizzes related to *related rates, linear approximations, and differentials.*	
	Leibniz in Process - 3	Gold	It is awarded for achieving an average score above 61 points in the mini-quizzes related to *curve sketching and optimization*.	
	Riemann in Process - 1	Gold	It is awarded for achieving an average score above 61 points in the mini-quizzes related to the *definite integral and the fundamental theorem of calculus*.	All the mini-quizzes scores are available.
	Riemann in Process - 2	Gold	It is awarded for achieving an average score above 61 points in the mini-quizzes related to integration techniques: *substitution rule, integration by parts, and trigonometric integrals*.	
	Riemann in Process - 3	Gold	It is awarded for achieving an average score above 61 points in the mini-quizzes related to integration techniques: *trigonometric substitution, integration of rational functions, and other relevant strategies for integration.*	
	Newton in Process - 1	Gold	It is awarded for achieving an average score above 61 points in the mini-quizzes related to *areas and volumes*.	All the mini-quizzes scores are available.
	Newton in Process - 2	Gold	It is awarded for achieving an average score above 61 points in the mini-quizzes related to *arc length, area of a surface of revolution, and average value of a function*.	
	Newton in Process - 3	Gold	It is awarded for achieving an average score above 61 points in the mini-quizzes related to *applications of integral calculus to physics and engineering*.	

Table 1 - Mini-Quizzes Digital Badges Description

Category	Badge Name	Levels	Criterion for Earning the Badge	The badge is awarded when:
Midterms and Final Exams	Expert on Applications of Differential Calculus	Gold	It is awarded for achieving a perfect score (100 points) in the first midterm exam on differentiation rules and applications of differential calculus for functions of a single real variable.	The first midterm is evaluated.
		Silver	It is awarded for achieving a score between 91 and 99 points in the first midterm exam on differentiation rules and applications of differential calculus for functions of a single real variable.	
		Bronze	It is awarded for achieving a score between 81 and 90 points in the first midterm exam on differentiation rules and applications of differential calculus for functions of a single real variable.	
	Expert on Integration	Gold	It is awarded for achieving a perfect score (100 points) on the second midterm exam, which primarily focuses on the definite integral and integration techniques.	The second midterm is evaluated.
		Silver	It is awarded for achieving a score between 91 and 99 points on the second midterm exam, which primarily focuses on the definite integral and integration techniques.	
		Bronze	It is awarded for achieving a score between 81 and 90 points on the second midterm exam, which primarily focuses on the definite integral and integration techniques.	
	Expert on Applications of Integral Calculus	Gold	It is awarded for achieving a perfect score (100 points) on the final exam, which primarily focuses on applications of integral calculus for functions of a single real variable.	The final exam is evaluated.
		Silver	It is awarded for achieving a score between 91 and 99 points on the final exam, which primarily focuses on applications of integral calculus for functions of a single real variable.	
		Bronze	It is awarded for achieving a score between 81 and 90 points on the final exam, which primarily focuses on applications of integral calculus for functions of a single real variable.	

Table 2 - Exams Digital Badges Description

The badges in the Exams category (refer to Table 2) are awarded at the end of each course unit, thus marking a course milestone. These badges acknowledge the student's domain of the topics covered in a course unit. Different from the Mini-Quizzes badges category, the Exam badges recognize the student's exceptional effort in each unit because they are awarded exclusively to those who stand out, i.e., students with exam scores greater than 80 points. Note that the badges' name begins with the phrase *"Expert on …"* as the main objective of this category is to make their recipients experience a sense of satisfaction for their achievement and appreciate the recognition bestowed upon them. Therefore, this category of badges aims to create an environment of competition where students can proudly share their accomplishments with their peers, generating a culture of academic success within the group.

MATH 202 is a course that demands considerable effort from students. In addition to the aforementioned digital badges, we incorporated a category to reward perseverance throughout the course. This aspect is particularly important for courses with a significant workload, such as ours, including 28 worksheets. Granting badges upon the successful completion of a specified number of worksheets recognizes the student's sustained effort and dedication, thereby making the long academic journey more manageable for them. Table 3 provides a detailed description of this badge category associated with the course worksheets.

As mentioned earlier, MATH 202 incorporates two mini-application projects with the objective of applying the mathematical concepts studied in this course to solve real-life problems, reducing the gap between theory and practice [12]. These projects encompass activities such as constructing prototypes, conducting experiments, using a particular software, and programming, thus promoting creativity, critical thinking, problem-solving skills, and teamwork. To recognize and identify students with these skills, we introduced a badge category based on the grades from the MAPs (refer to Table 4). The badges in this category not only acknowledge the student's outstanding work but also assist faculty in identifying potential candidates for undergraduate research assistant (RA) roles. Given the challenges in finding RA for undergraduate projects, these badges facilitate the selection process by providing a list of candidates based on their achievements in this category. Acknowledge that these badges are single-level and awarded only to students with a perfect score of 100 points, thus refining the selection process.

Category	Badge Name	Levels	Criterion for Earning the Badge	The badge is awarded when:
Worksheets	Commitment	Gold	It is awarded for achieving an average score between 91 and 100 points on the worksheets related to differential calculus for functions of a single real variable, emphasizing the dedication to completing them during the initial third of the semester.	All the worksheets scores are available.
		Silver	It is awarded for achieving an average score between 81 and 90 points on the worksheets related to differential calculus for functions of a single real variable, emphasizing the dedication to completing them during the initial third of the semester.	
		Bronze	It is awarded for achieving an average score between 71 and 80 points on the worksheets related to differential calculus for functions of a single real variable, emphasizing the dedication to completing them during the initial third of the semester.	
	Consistency	Gold	It is awarded for obtaining an average score between 91 and 100 points on the worksheets related to integration techniques, acknowledging the consistency in completing them throughout the second part of the semester.	All the worksheets scores are available.
		Silver	It is awarded for obtaining an average score between 81 and 90 points on the worksheets related to integration techniques, acknowledging the consistency in completing them throughout the second part of the semester.	
		Bronze	It is awarded for obtaining an average score between 71 and 80 points on the worksheets related to integration techniques, acknowledging the consistency in completing them throughout the second part of the semester.	
	Dedication	Gold	It is awarded for achieving an average score between 91 and 100 points on the worksheets related to applications of integral calculus for functions of a single real variable, acknowledging the dedication demonstrated in solving them during the last part of the semester.	All the worksheets scores are available.
		Silver	It is awarded for achieving an average score between 81 and 90 points on the worksheets related to applications of integral calculus for functions of a single real variable, acknowledging the dedication demonstrated in solving them during the last part of the semester.	
		Bronze	It is awarded for achieving an average score between 71 and 80 points on the worksheets related to applications of integral calculus for functions of a single real variable, acknowledging the dedication demonstrated in solving them during the last part of the semester.	

Table 3 - Worksheets Digital Badges Description

Category	Badge Name	Levels	Criterion for Earning the Badge	The badge is awarded when:
Mini Application Projects - MAPs	Outstanding MAP 1	Single Level	It is awarded for obtaining a perfect grade (100 points) in MAP 1, highlighting the students ability to apply the concepts of differential calculus in solving real-world problems.	The assignment is evaluated.
	Outstanding MAP 2	Single Level	It is awarded for obtaining a perfect grade (100 points) in MAP 1, highlighting the students ability to apply the concepts of integral calculus in solving real-world problems.	The assignment is evaluated.

Table 4 - MAPs Digital Badges Description

The last category in our badge architecture is tied to the course final score and it serves as a holistic recognition of a student's dedication and performance throughout the course (see Table 5). The “Isaac Newton” badge has four different levels: three (Gold, Silver, and Bronze) dedicated to recognizing exceptional students who distinguished themselves, and one (Copper) indicating the successful completion of the course. The main objective of the copper level is to transmit the following message to the students: while they have successfully passed the course, it encourages them to do better in their next mathematics course, striving to obtain a bronze, silver, or even a gold badge. Like the MAPs badge category, the Final Score badge can aid faculty in identifying potential teaching assistants (TA). Specifically, if a student holds a "Gold Isaac Newton" badge, this means that the student has mastered the course topics, thus fulfilling the first requirement for a TA. Consequently, this enables faculty to focus only on evaluating the students' teaching skills when considering them for TA positions.

Category	Badge Name	Levels	Criterion for Earning the Badge	The badge is awarded when:
Final Grade	Isaac Newton	Gold	It is awarded to those students who achieve a final grade between 96 and 100 points in the course, demonstrating exceptional performance.	Final course grades are available.
		Silver	It is awarded to those students who achieve a final grade between 91 and 95 points in the course, demonstrating outstanding performance.	
		Bronze	It is awarded to those students who achieve a final grade between 85 and 90 points in the course, demonstrating very good performance.	
		Copper	It is awarded to all students who passed MATH 202, i.e. those who achieved a grade between 61 and 84 points.	

Table 5 - Final Scores Digital Badges Description

In the design of a badge architecture, the name assigned to each badge is relevant, as it should be meaningful and appealing to students. It is worth noting that the Mini-Quizzes and Final Scores badge categories, introduced in Tables 2 and 5, are named after renowned mathematicians who are pioneers of calculus. The use of mathematicians' names in our badge architecture is not merely a formality; it serves two main objectives. First, it pays tribute to their intellectual legacy, and second, it aims to inspire students by connecting their own achievements during the course to those of brilliant mathematicians. As a result, the incorporation of mathematicians' names in the proposed badge architecture creates a motivating environment for students seeking excellence in MATH 202.

c. Badge System Platform

When implementing a badge architecture, the first decision involves choosing the right platform to use. While the FSBPI suggests using an open-source badge system for the initial development, we deviated from this recommendation by integrating our MATH 202 badge architecture into our LMS, called Galileo Educational System (GES) [13]. This decision was driven by another key suggestion of the FSBPI that highlights the importance of sharing the workload and involving university departments with expertise in areas such as information technologies and graphic design. The integration of our badge architecture into GES has significantly enhanced the efficiency of various tasks for professors. More precisely, our badge system platform allows them to easily create, edit, and delete badges. Even more, it also lets instructors create all the badges in one section of the course and then efficiently copy them to the rest of the sections, thus guaranteeing consistency. In terms of the awarding process, the system platform provides automation when the badges are linked to the grades of one or more assignments already defined in the course. This automatic process allows the faculty to create all the badges in the architecture at the beginning of the course and then simply let the platform do the awarding process during the course term. It is important to mention that the platform also allows manual badge awards, adding flexibility to the process. On the other hand, with the bonus feature of a dashboard (see Figure 1), professors can easily track and assess the student's achievements. This dashboard lets professors make informed academic decisions based on the awarded badges. Overall, the integration of our badge architecture into the GES has simplified and expedited the badge-related tasks for faculty. These outcomes align with the FSBPI's commitment to providing a user-friendly badge platform.

The integration of the badge platform into our LMS not only provided faculty with efficient management tools but also offered students direct access to their earned badges. A relevant bonus feature of our platform is to provide students with the possibility of sharing their badges on various social networks (such as Facebook, LinkedIn, X, and Instagram, among others). According to [14], allowing students to showcase their academic digital badges on social networks formalizes reputation and recognition within the academic community.

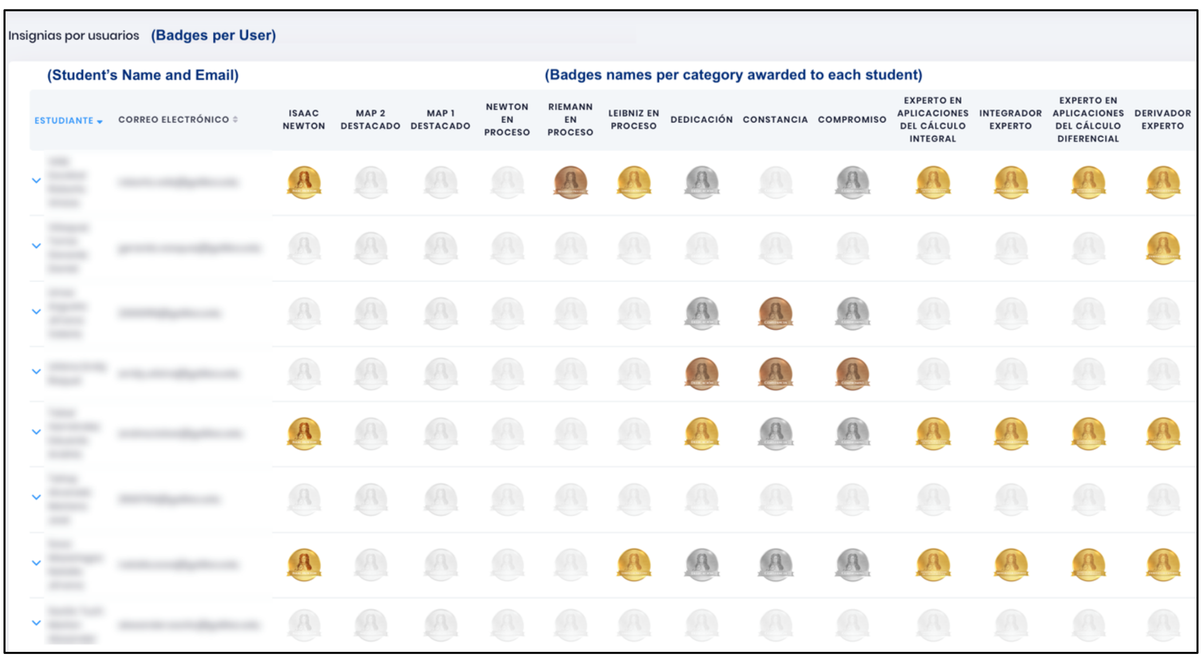

Figure 1 - Example of the badge dashboard integrated into the GES LMS.

Designing and creating the badge images is also a challenging task. The image design for our MATH 202 badge architecture was a collaborative effort involving a team of graphic designers. To ensure precision, we provided these experts with the detailed badge descriptions outlined in Tables 1 to 5. After several iterations and discussions, we obtained the visual representations used in the proposed badge architecture. See Figure 2 for some examples of the badge images designed for the Final Scores Badge category. To enhance flexibility and enable independent adjustments by faculty members, the graphic design team provided us with a set of predefined templates through the *Canva platform*. Canva is an open and user-friendly graphic design tool that facilitates image modifications, thus allowing faculty to adjust the badges to their preferences. This approach ensured a cohesive and visually appealing badge set while empowering faculty to effortlessly customize badge images, thus reducing the workload and eliminating the need for graphic design skills. Figure 3 shows a sample of the mentioned templates in the Canva platform.

Figure 2 – Images of badges for the four levels (gold, silver, bronze, and copper) in the Final Scores badge category. "Matemática 2 (208)" stands for the course name in Spanish.

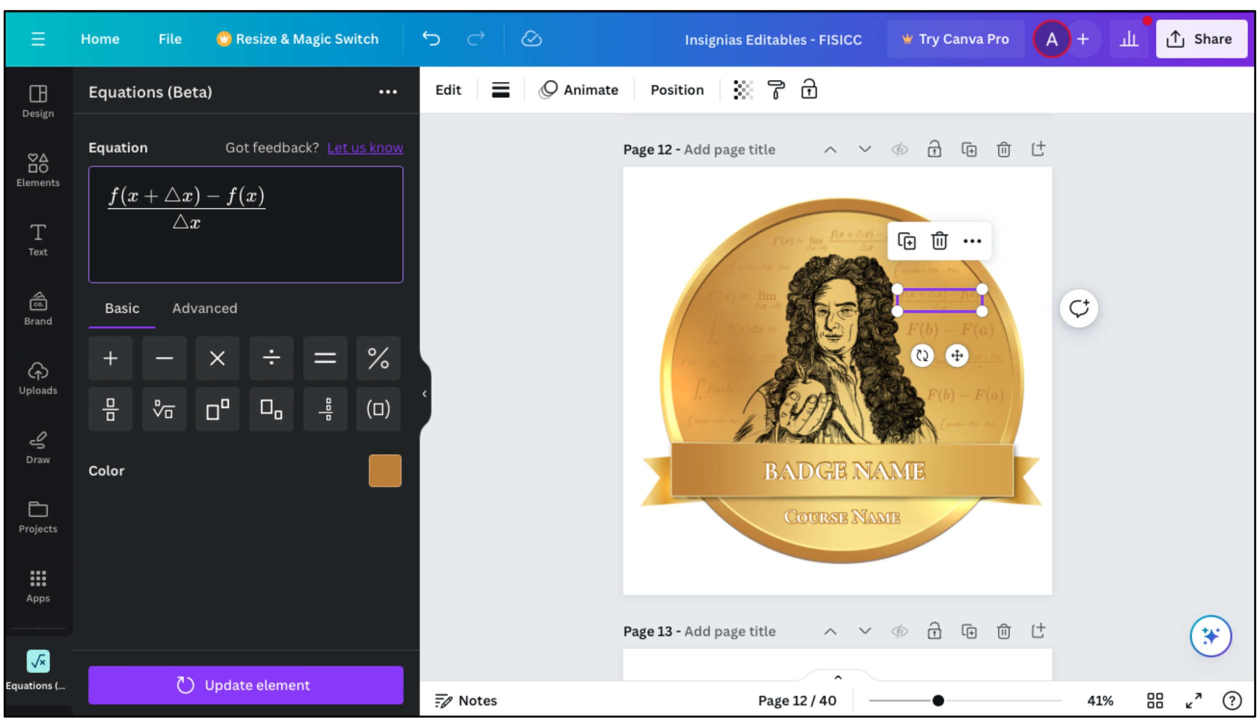

Figure 3 - Example of a badge image template designed by the graphics design team and then integrated into Canva for faculty customization.

d. Badge Program Implementation

We conclude this section by briefly discussing how we introduced the badge architecture to faculty and students and how to assess its effectiveness by following the guidelines in the *badge program implementation* category of the FSBPI. After realizing the need for a pedagogical tool to enhance motivation and engagement in mathematics courses for engineering majors, all MATH 202 instructors decided to actively participate in the design and implementation of a badge architecture, i.e., they recognize the purpose and value of the project. Due to the coordination among the nine sections of MATH 202, sharing not only the syllabus but also the activities, the implementation process was seamless since all the badge categories (see Tables 1 to 5) are associated with assignments' scores. The FSBPI recommends training TAs to ensure grade consistency across multiple sections. In our case, we achieve this goal through the implementation of grading rubrics and with a TA coordinator responsible for overseeing this task.

As this is the first implementation of a badge architecture in MATH 202, professors unanimously agree on the need for ongoing evaluation and potential revisions. The examination plan incorporates the design of a questionnaire to gauge students' motivation during and after implementing the badge architecture in MATH 202. Additionally, scalability plans are in place; if the outcomes are promising, the badge architecture will be applied in other mathematics courses. The overall impact of the proposed badge architecture on students' motivation and engagement in this course will be reported in the second part of this paper [15].

The FSBPI highlights the importance of guaranteeing the students understand the value and purpose of the badge architecture. To address this issue, we introduced the badge architecture to students on the first day of classes. According to [8], badge architectures can contribute to organizing the syllabus more engagingly, showing a clear course timeline, and presenting the content in the form of a conceptual map. Following this idea, we designed an appealing presentation to communicate the details and significance of the badges to the students. The main objective of this introductory session is to familiarize the students with the syllabus and connect it with the structure and benefits of the badge architecture. Even more, each week at the beginning of the class, instructors proudly present a list of students who have earned badges for their exceptional performance in the previous week. This practice serves a dual purpose: to keep students well-informed about the badges and to spotlight their achievements. This public acknowledgment celebrates individual success and creates a sense of excellence within the classroom.

4. Conclusions

The design and implementation of a badge architecture into MATH 202, guided by the FSBPI, proved to be a challenging yet rewarding duty. The recommendations of this framework provided a structured approach to organize the complex tasks involved and, thus, balance the faculty workload.

The proposed badge architecture seems promising in achieving the outlined goals of boosting student engagement, motivation, and academic success. Note that our badge architecture incorporates specific badges designed to directly recognize and reward students who excel in their academic performance. Such badges, named after distinguished mathematicians, aim to motivate exceptional students and encourage them to achieve top grades in the course. Furthermore, within our badge architecture, there are two categories (MAPs and Final Grade) that can assist faculty in identifying prospective candidates for roles as RAs and TAs. Those students aspiring to secure an RA or TA position will strive to obtain the badges in the mentioned categories.

According to [16], in certain undergraduate courses, the incorporation of badges was found to be less motivating and occasionally demotivating for lower-level learners. Therefore, different from traditional badge architectures (see e.g., [17, 18, 19]), our scheme also aims to help below-average students do better in the course. More precisely, the Mini-Quizzes badge category may serve as an academic guide for those students by showing *graphically* their strengths and weaknesses, thus offering valuable insights into their learning process. In summary, the proposed badge architecture holds the potential to create positive and memorable experiences within the course and reduce the debate on whether badges are related to lower levels of intrinsic motivation [20]. We expect that our architecture achieves a uniform attitude among most students towards the challenges presented, thus avoiding the differences found in some cases, e.g. [21].

Finally, the MATH 202 badge architecture demonstrates remarkable flexibility, making it easily adaptable to other courses within the engineering curriculum. Its versatile design allows a smooth integration and customization to meet the specific needs and objectives of different subjects within engineering. It can be adjusted to prioritize evolving learning objectives and mirror the values of a program as it advances and broadens its scope [22]. As a result, our badge architecture provides a scalable tool for enhancing student engagement and motivation across multiple disciplines. Even more, as required by [23], our badge architecture offers valuable insights into the students' learning approaches, providing instructors with information to enhance their instructional delivery methods.

5. Acknowledgements

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