Manna Methodology: A Novel Approach to Education 5.0 Through Learning and Socio-Emotional Assessment in IoD Bootcamps

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Abstract: This study explores the practical application of Education 5.0 through a methodology that integrates exponential technologies, emphasizing the Internet of Drones (IoD) to enhance students' technical and socio-emotional competencies. Conducted within the Manna Ecosystem—Brazil's largest platform for teaching, research, and innovation in Exponential Technologies—the study evaluates the impact of personalized pedagogical approaches in public schools. The proposed methodology utilizes David Kolb's learning style model (Accommodator, Converger, Assimilator, and Diverger) and specific socio-emotional competencies, including emotional awareness, emotional regulation, and relationship skills. Based on these learning profiles and participants' socio-emotional competencies, teams were organized with complementary profiles, using Artificial Intelligence to create personalized groups that promoted greater engagement and synergy, enhancing performance in innovation activities. Four case studies were conducted, comparing experimental groups formed with the personalized methodology and control groups organized randomly, through diagnostic, formative, and summative assessments. Statistical analyses revealed that the experimental group showed significantly superior performance compared to the control group, highlighting the potential of the methodology in creating an interactive and collaborative learning environment. These findings reinforce the relevance of integrating exponential technologies, such as IoD, with active and adaptive teaching methodologies, contributing to the advancement of Education 5.0 and preparing students for the challenges of the 21st century.

1 INTRODUCTION

The digital transformation is reshaping how we live, work, and learn, blurring the boundaries between online and offline into a paradigm Floridi describes as "onlife." In this new reality, technology seamlessly integrates into daily life, creating profound changes (Floridi, 2014). This scenario expands education's role in cultivating skills that transcend technical knowledge, emphasizing socio-emotional competencies essential for today's world. In response, Education 5.0 emerges as an approach that blends technological advancements with a humanistic focus, fostering holistic development and preparing individuals to tackle the 21st century's complex challenges. (Hussin, 2018). This educational perspective extends beyond keeping pace with technological innovation. It leverages exponential technologies, such as Artificial Intelligence (AI), the Internet of Things (IoT), and the Internet of Drones (IoD), to enrich learning experiences. These technologies foster personalization, protagonism, and collaboration in inclusive, interconnected educational environments, aligning with the onlife experience and addressing contemporary societal needs. (World Economic Forum, 2020).

Recent literature emphasizes Education 5.0 as an approach that combines technological advancements with human development, promoting comprehensive training for a world in transformation (Xu et al., 2018), (Popenici and Kerr, 2017), (Torres et al., 2019). This approach aims to go beyond technical skills, incorporating socio-emotional competencies, creativity, and the capacity for innovation, thus preparing citizens to proactively and collaboratively tackle contemporary challenges (Salmon, 2019), (Hussin, 2018), (Ford, 2021).

For the Manna_Team (Manna team of scientists), one of the pioneering groups in this area, Education 5.0 represents the synthesis of Exponential Technologies and Exponential People, characterized by happi-

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ness, creativity, social intelligence, and the capacity to drive innovation, contributing to collective well-being. The union between individuals and exponential technologies enables the development of exponential schools and universities, forming a generation of "5.0 Citizens," equipped with hard skills and soft skills, ready to drive innovations with a positive impact on society. In this sense, the culture of innovation is nurtured from preschool education and extends to Elementary School, High School, Technical Education, and Higher Education, fostering lifelong innovation skills and adaptation, which continuously foster new businesses and solutions for environmental, social, and governance challenges.

However, Education 5.0 faces significant challenges, particularly in bridging the gap between universities, notably in engineering and computing courses—responsible for hard skills development—and public schools, which are run with dedication by pedagogues and educators. The Manna_Team addresses this challenge directly by integrating practical kits of Artificial Intelligence, IoD, IoT, Robotics, and Games into public schools, promoting soft skills development through an innovative methodology known as MannaDrigar. This methodology combines learning styles such as Accommodating, Converging, Assimilating, and Diverging with socio-emotional competencies (emotional awareness, emotional regulation, relationship skills), fostering a personalized approach adapted to students' demands (Luckin et al., 2016) (Kolb and Kolb, 2005).

This paper aims to present the MannaDrigar Methodology, developed as a strategy that combines learning styles and socio-emotional competencies to maximize student engagement and performance in innovation activities conducted in Manna_Team Bootcamps. The methodology proposes analyzing participants' learning styles and socio-emotional competencies to organize teams with complementary profiles, seeking greater engagement and synergy to foster better performance in practical innovation activities.

As a case study, we applied the methodology in Manna_Team Bootcamps, immersive experiences in Exponential Technologies, with a special focus on the Internet of Drones (IoD). During the bootcamps, participants were divided into two groups: control (without applying the methodology) and experimental (with applying the methodology). These groups were evaluated in three stages: diagnostic assessment at the beginning of the bootcamp to measure learning styles and socio-emotional skills; formative assessment during the bootcamp to monitor progress in each session; and summative assessment at the end, which measured the experimental groups' performance through innovation competitions. This study aims to demonstrate the impact of personalization, based on learning styles and socio-emotional skills, on developing technical and interpersonal skills.

Building the future involves broad access to Exponential Technologies and knowledge dissemination, making it accessible to everyone. When these technologies are used to develop soft skills and integrate curricular content, they offer a unique opportunity for educational innovation and disruption. This paper, therefore, adopts the Internet of Drones as a central technology in the bootcamp experiments, seeking to demonstrate the potential of personalized methodologies for comprehensive student development.

2 LITERATURE REVIEW

This study builds upon two systematic literature reviews offering a comprehensive perspective on methodologies and technologies within the Education 5.0 framework. The first review, "Systematic Literature Review on Instruments and Strategies for Learning Assessment in the Context of Education 5.0," examined methodologies and tools designed to personalize learning and integrate technical and socio-emotional skills. Using the Parsifal tool, the initial review retrieved 241 articles, from which 30 were selected based on rigorous inclusion and exclusion criteria. Among these, 12 articles underwent an in-depth evaluation, highlighting approaches such as social interactions and collaborative platforms (25% of the studies), survey techniques and online questionnaires (33%), as well as probing and rubric-based assessments (17%). Emerging technologies, such as the metaverse and blockchain, were explored in 8% of the articles, while 17% recommended combining formative and summative assessments as an effective evaluation practice.

The second review, "Systematic Literature Review on Artificial Intelligence in the Context of Education 5.0," explored the application of technologies such as Artificial Intelligence (AI) and the Internet of Drones (IoD) in educational contexts. Initially, 224 articles were identified, with 32 pre-selected and 14 analyzed in detail. Results revealed the growing adoption of AI to personalize learning and provide individualized feedback. Approximately 21% of the analyzed studies examined gamification as a motivation and engagement strategy, while 29% highlighted recommendation systems that tailor content to individual needs, creating a dynamic and collaborative learning environment.

Both reviews also highlighted challenges, particularly in the development of socio-emotional skills, which were identified in only 15% of the articles. This gap emphasizes the need for further research to integrate these skills into AI-based pedagogical practices, essential for preparing students for the complex demands of contemporary society.

2.1 Preliminary Studies

Annually, the Manna_Team organizes two bootcamps during Expoingá, one of the largest agricultural fairs in Brazil, held in Maringá. These events develop educational methodologies and practices focused on innovation, emphasizing the development of technical and socio-emotional competencies, especially for students and teachers from public schools in the northwest region of Paraná. The Manna Galáxias Bootcamp hosted 65 teachers, while the Manna Agro Bootcamp involved 119 students. In both events, participants were challenged to use innovation techniques and develop creative solutions in teams, encouraging collaboration and practical application of the presented concepts.

In 2023, a study with 45 volunteers assessed the participants' learning styles according to Kolb's model, which identifies four profiles: Accommodator, Converger, Assimilator, and Diverger. The choice of Kolb's model was based on the findings from our systematic literature reviews (Section 2), which highlighted the effectiveness of personalized teaching methodologies based on learning styles for developing technical and socio-emotional competencies. Results showed that the Accommodator style was the most frequent among participants, followed by Converger and Diverger, indicating a general preference for hands-on experiences.

Applying Kolb's model in the bootcamps allowed educational activities to align with students' learning preferences, enhancing engagement and content assimilation. Details on how learning styles and socio-emotional competencies were integrated into the study's methodology are presented in Section 3.

The study also analyzed the organization of participants into teams based on their learning styles and socio-emotional competencies, investigating whether this organization would result in better performance compared to random team formation. It was observed that participants demonstrated flexibility in their learning modes, using a secondary style that complemented their predominant skills.

The hypothesis tested was that pre-classifying students and teachers based on their learning styles and socio-emotional competencies could foster a more harmonious group dynamic, promoting academic performance and personal development. To explore this hypothesis, a correlation matrix of learning styles was analyzed, presented in Figure 1.

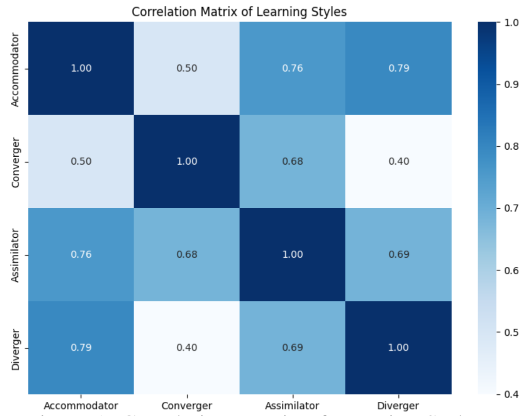

Figure 1: Correlation Matrix of Learning Styles.

A high correlation (0.79) was observed between the Accommodator and Diverger styles, and a moderate correlation (0.68) between Converger and Assimilator, suggesting that predominant styles tend to complement each other, positively influencing team dynamics.

Based on these results and the ranking of teams at the end of the bootcamp, this study sought to expand the analysis of the effectiveness of pre-classifying students, considering the development of academic skills, collaborative abilities, and socio-emotional skills, aligning with Manna's mission to promote Education 5.0 by integrating exponential technologies with competency development.

2.2 Study Objectives

The objective of this study is to investigate the effectiveness of the teaching, learning, and assessment methodologies used in the IoD bootcamps promoted by the Manna_Team. The focus is on developing participants' technical, collaborative, problem-solving, and socio-emotional skills, preparing them for the challenges of the 21st century within the context of Education 5.0.

This study evaluates how these methodologies contribute to the enhancement of students' competencies, examining the impact of personalized teaching based on learning styles and socio-emotional competencies. It also seeks to measure progress in the development of these skills throughout the bootcamp.

The hypothesis tested is:

- *H1: The pre-classification of students before the bootcamp, based on learning styles and socio-*

emotional competencies, results in better academic performance and personal development compared to random organization.

The research questions are:

- *Q1: How do IoD bootcamps influence the development of students' technical skills?*
- *Q2: In what ways do IoD bootcamps impact participants' socio-emotional competencies?*
- *Q3: What is the effect of personalized teaching, based on learning styles and socio-emotional competencies, on students' academic performance?*
- *Q4: What are the differences in skill development between students in the experimental group and the control group?*
- *Q5: How do students perceive the effectiveness of IoD bootcamps in their learning and personal development?*

By addressing these questions, the study aims to provide insights into the effectiveness of the educational methodologies implemented by Manna, contributing to the understanding of how the pedagogical approaches adopted in the bootcamps can prepare students for the challenges of Education 5.0.

2.3 BootCamp Description

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2.4 Bootcamp Description

This study was based on the immersive IoD bootcamp, named "Holiday of the Beasts" ("Férias das Feras"), held during the school vacation in January 2024 in the cities of Maringá, Campo Mourão, Cianorte, and Paranavaí in Paraná, Brazil. Geared toward public school students, the bootcamp lasted five days, with four hours of daily activities, providing a practical and collaborative experience that integrated the development of technical and socio-emotional skills.

Organized by Manna, the primary objective of the bootcamp was to introduce participants to IoD concepts and promote essential 21st-century socio-emotional skills, such as problem-solving, collaboration, and critical thinking.

The curriculum was structured into ten modules, covering everything from a theoretical introduction to IoD to practical drone piloting activities and presentations of innovative projects. The topics covered were:

- **Module 1.** *Introduction to the Internet of Drones* – Overview of IoD.
- **Module 2.** *The Evolution of the Internet and the Drone Era* – Development of the internet and drone integration.
- **Module 3.** *Building a Joystick with Arduino* – Practical activity in joystick construction.
- **Module 4.** *Drone Classification and Applications* – Categories of drones and their applications.
- **Module 5.** *Essential Drone Components* – Study of the main components.

- **Module 6.** *Drone Programming and Automation* – Introduction to drone programming.
- **Module 7.** *Flight Modes and Drone Control* – Exploration of different flight modes.
- **Module 8.** *Ethics and Responsibility in Drone Use* – Reflection on the safe and ethical use of drones.
- **Module 9.** *Drone Piloting Practice* – Practical activity in drone piloting.
- **Module 10** *Project Presentation and Evaluation* – Presentation of the developed projects.

The "Holiday of the Beasts" bootcamp ("Férias das Feras") provided students with an opportunity to develop technical and socio-emotional competencies through a practical and immersive approach. The final idea competition allowed students to demonstrate their innovation skills and application of IoD concepts in real-world scenarios.

This event differed from other bootcamps organized by Manna, such as those held at Expoingá, by offering an intensive approach with an emphasis on practical drone use and a playful, immersive experience, especially adapted for the school vacation period. The collaborative environment and challenging activities contributed to the enhancement of students' skills, aligning with the principles of Education 5.0.

3 TEACHING METHODOLOGY

This section outlines the study's methodology, covering the context of the Internet of Drones (IoD) bootcamps conducted in four cities in Paraná, Brazil. It describes the teaching structure based on Kolb's learning styles and socio-emotional competencies, the use of the K-means algorithm for group formation, the assessment methods (diagnostic, formative, and summative), cluster validation techniques, and ethical considerations.

The study took place in four cities in Paraná, Brazil, during January 2024, involving 195 participants: Maringá (January 8–12, 50 participants), Cianorte (January 15–19, 78 participants), Paranavaí (January 29–February 2, 37 participants), and Campo Mourão (January 29–February 2, 30 participants). A consistent methodology was applied in all case studies conducted across these locations.

The methodology combined learning styles and socio-emotional competencies with personalization techniques mediated by AI. Experimental groups were formed based on Kolb's Learning Style Inventory (LSI) (Kolb and Kolb, 2005) and the Socio-Emotional Competencies Scale (SECD) (Winsler et al., 2014), using the K-means algorithm to cluster participants into personalized and diverse groups. Control groups were organized randomly.

The teaching methodology followed Kolb's experiential learning model (Kolb and Kolb, 2005), which identifies four learning styles:

- **Converger.** Applies theories to practical problems, seeking correct solutions.
- **Diverger.** Learns by observing and generating ideas, viewing multiple perspectives.
- **Assimilator.** Organizes information logically, reflecting on theories without immediate application.
- **Accommodator.** Learns by doing, adapting to new situations through practical experimentation.

3.1 Group Formation with K-Means

The K-means algorithm was selected for its efficiency in grouping students based on quantitative characteristics, including learning styles and socio-emotional competencies (Hartigan et al., 1979), (Hamerly and Elkan, 2003). Its application aimed to maximize diversity within each team, fostering a collaborative and dynamic environment. (Arthur and Vassilvitskii, 2007).

Before the bootcamp, participants completed the LSI (Kolb and Kolb, 2005) and SECD (Winsler et al., 2014), and their scores were used for clustering. Data normalization was conducted using *z-scores* to ensure equal weighting of all variables (Felder, 2002). Four clusters were defined, aligning with Kolb's learning styles. The *k-means++* method was employed for initializing the clustering process, with Euclidean distance serving as the similarity metric(Arthur and Vassilvitskii, 2007), (Hamerly and Elkan, 2003).

Each group, whether experimental or control, was composed of 3 to 5 students. The logistical organization allowed the bootcamps to take place simultaneously, ensuring that all students received the necessary attention. The use of K-means promoted balanced teams, where students with different profiles contributed in complementary ways, optimizing technical and socio-emotional development.

The pre-tests conducted (Kolb's Learning Style Inventory and the Socio-Emotional Competencies Scale) were used to form the experimental and control groups. The experimental group was organized based on participants' primary and secondary learning styles and socio-emotional competencies, while the control group was randomly assigned. No additional pre-test was conducted to compare initial performance levels between groups, as this was not within the scope or objectives of the study, which focused on evaluating the impact of personalized teaching methodologies during the bootcamp.

The teaching process was standardized for all groups, with no differentiation in instructional methods. Personalization occurred exclusively in the experimental group's team formation, where participants were grouped based on their learning styles and socio-emotional competencies. The impact of this diversity, particularly during assessments and the final innovation competition, is analyzed and discussed in Section 4.

3.2 Cluster Validation

To ensure the adequacy of the number of clusters, we applied the elbow method (Ketchen and Shook, 1996) and the silhouette index (Dudek, 2020). The elbow method indicated that four clusters were appropriate, aligning with Kolb's styles. The silhouette index had an average of 0.65, suggesting well-defined clusters.

3.3 Bias Minimization and Ethical Considerations

To guarantee impartiality and validity, teachers were not informed of the group formations beforehand, minimizing instructional biases. Evaluations were blinded, ensuring that assessors were unaware of group classifications. Standardized assessment tools were used to ensure consistency and comparability of results.

In ethical terms, the study followed guidelines for research with minors, including informed consent from parents or guardians. Data privacy was protected through anonymization, and procedures were approved by the Research Ethics Committee.

3.4 Debates on Learning Styles

Although Kolb's learning styles are widely used, the literature questions their effectiveness. Studies such as (Pashler et al., 2008) and (Kirschner, 2017) argue that there is no robust evidence that adapting instruction to individual styles significantly improves academic outcomes. Nevertheless, Kolb's model was chosen due to its relevance in the context of IoD Bootcamps, which are intensive and hands-on. Personalizing instruction based on learning styles was considered effective in creating dynamic and collaborative environments, suited to active methodologies and the use of exponential technologies.

3.5 Availability of Research Artifacts

To promote transparency and replicability, all research artifacts are available in a public repository, including anonymized data, code used in K-means, statistical analyses, and supplementary materials. The repository can be accessed at: [1].

3.6 Learning Assessment Dimensions

The assessment was structured into three dimensions: diagnostic, formative, and summative, allowing the tracking of participants' development at different stages (Black and Wiliam, 2009), (Bennett, 2011), (Nicol and Macfarlane-Dick, 2006).

The diagnostic assessment, conducted at the beginning of the bootcamp, aimed to identify students' prior knowledge and socio-emotional competencies, using the SECD (Winsler et al., 2014). This was essential for personalizing the activities.

The formative assessment was performed at the end of each session, with objective questions related to the covered content, allowing continuous feedback and immediate adjustments to activities (Halili and Zainuddin, 2015), (Bennett, 2011).

The summative assessment took place during the Innovation Competition, where students applied the acquired knowledge to solve practical problems related to IoD. Project evaluation was carried out by a jury, following a detailed rubric with criteria on originality, practical applicability, technical complexity, and teamwork (Jones et al., 2020), (Andrade, 2005).

This combination of assessments allowed for monitoring of students' technical and socio-emotional development throughout the bootcamp, ensuring a continuous and personalized learning process.

3.7 Diagnostic Assessment

Before the bootcamp, we conducted a diagnostic assessment based on the SECD (Winsler et al., 2014), which measures skills such as emotional awareness, emotional regulation, and relationship skills. Each competency was rated on a Likert scale from 1 to 5, where "Never" represents 1 point and "Always" represents 5 points.

The data collected guided group formation and personalized activities, ensuring adequate support for socio-emotional development (Salovey and Mayer, 1990), (Mayer, 2002), (Neubauer and Freudenthaler, 2005).

[1] Available at: https://github.com/tmadrigar/experimental-package-CSEDU

3.7.1 Application of the K-Means Algorithm

The K-means algorithm was applied to cluster students based on their learning styles and socio-emotional competencies (Hartigan et al., 1979), aiming to maximize style diversity within each group and foster a collaborative environment (Manolis et al., 2013).

Students completed the Learning Style Inventory (LSI) (Kolb and Kolb, 2005) and the Socio-Emotional Competencies Scale (SECD) (Winsler et al., 2014). The scores identified their predominant and secondary learning styles, as well as socio-emotional skills such as self-control, empathy, collaboration, and resilience.

The data were normalized using *z-scores* (Felder, 2002). We employed the *k-means++* method to strategically select initial centroids (Arthur and Vassilvitskii, 2007). The similarity metric used was Euclidean distance (Hamerly and Elkan, 2003):

$$\mathrm{Dist}(x_i, c_j) = \sqrt{\sum_{d=1}^{D} (x_{i,d} - c_{j,d})^2}$$

where x_i represents a student's scores, and c_j is the cluster centroid.

The K-means clustering algorithm is described as follows:

Data: Set of students with learning style and socio-emotional competency data
Result: Student groups clustered based on their learning styles
Initialization:
- Select k initial centroids (or use *k-means++*);
- Assign each student to the nearest centroid.

while *centroids are not stabilized* **do**
  for *each student* **do**
    Calculate the distance between the student and each centroid; Assign the student to the nearest centroid;
  end
  for *each group* **do**
    Recalculate the centroid by taking the mean of students' points in the group.
  end
end
Return the formed groups.

Algorithm 1: K-Means Clustering Algorithm.

After clustering, experimental groups were formed by considering primary and secondary learning styles, as well as socio-emotional competencies. This approach promoted diverse teams where different profiles complemented each other, maximizing collaborative potential and aligning with the principles of Education 5.0.

3.8 Formative Assessment

Formative assessment was implemented throughout the bootcamp to provide continuous feedback and enable methodological adjustments (Black and Wiliam, 2009), (Bennett, 2011).

Nine formative assessments were applied at the end of each session, each consisting of five objective questions on the concepts covered. Responses were collected via the *Kahoot* platform, which creates a real-time ranking and provides immediate feedback, fostering motivation and allowing adjustments as students progressed (Wang and Hannafin, 2014), (Hamari et al., 2017).

Formative assessment is aligned with constructivist learning theories, promoting the development of metacognitive and self-regulation skills (Piaget et al., 1952), (Vygotsky and Cole, 1978), (Nicol and Macfarlane-Dick, 2006).

3.9 Summative Assessment

The summative assessment was conducted through an Innovation Competition, challenging students to apply their knowledge to solve real-world problems related to IoD. Students, in teams, proposed innovative solutions in areas such as precision agriculture, environmental monitoring, logistics, and public safety.

We used tools like pitches and the Business Model Canvas to structure the solutions. Teams presented their proposals in 2-minute pitches, followed by questions from the evaluation panel.

To ensure objectivity, a detailed rubric was used (Jones et al., 2020), (Andrade, 2005), with criteria on Originality and Innovation (25%), Practical Applicability (20%), Technical Complexity (15%), Teamwork (25%), and Presentation (15%), as shown in Table 1.

The evaluation panel was composed of IoD experts, teachers, and industry professionals, ensuring impartiality. Final scores were calculated based on the established weights, resulting in the final ranking of each team.

4 RESULTS

This section presents the results of four case studies conducted in Maringá, Campo Mourão, Cianorte, and Paranavaí. It includes inferential statistical analyses comparing the performance of experimental and control groups, along with a discussion of individual results for each case study. Particular attention

Table 1: Evaluation Rubric for the Innovation Competition.

Criterion	Description	Weight (%)	Level 1 (1–2 pts)	Level 2 (3–4 pts)	Level 3 (5–6 pts)	Level 4 (7–8 pts)	Level 5 (9–10 pts)
Originality and Innovation	Creativity and innovation of the proposed solution.	25%	Minimal originality	Some originality	Moderately innovative	Innovative	Highly innovative and creative
Practical Applicability	Feasibility and practical applicability in a real-world context.	20%	Low feasibility	Some feasibility	Moderately feasible	Feasible	Highly feasible and practical
Technical Complexity	Level of technical complexity and appropriate use of IoD technologies.	15%	Minimal complexity	Some complexity	Moderately complex	Complex	Highly complex and sophisticated
Teamwork	Effectiveness of collaboration among team members.	25%	Minimal collaboration	Some collaboration	Moderately collaborative	Good collaboration	Excellent collaboration and dynamics
Presentation	Clarity, organization, and defense of the solution during the presentation.	15%	Unclear and disorganized	Some clarity and organization	Moderately clear and organized	Clear and organized	Highly clear, organized, and convincing

is given to formative assessment activities and innovation competitions, highlighting key findings about the effectiveness of the personalized methodology applied during the bootcamps.

The results reflect the application of the methodology described in Section 3, which includes personalized teaching through learning styles and socio-emotional competencies, as well as strategic group formation.

4.1 Inferential Statistical Analyses

To evaluate the methodology's effectiveness, inferential statistical analyses were conducted to compare the performance of experimental and control groups. An independent t-test revealed a statistically significant difference between the groups, with the experimental group achieving higher performance. The calculated effect size ($d = 0.6$) was considered moderate to high, suggesting a relevant impact of the methodology (Cohen, 1988).

ANOVA was applied to assess whether sociodemographic variables, such as age and gender, influenced student performance. The analysis revealed no significant effects, indicating that the observed differences were primarily attributable to the pedagogical methodology.

Confidence intervals of 95% were calculated for group means, providing greater robustness to the conclusions (Cumming, 2012). The analysis of effect sizes and confidence intervals reinforces that personalized teaching resulted in significantly superior performance in the experimental group.

4.2 Case Study 1

The first case study, conducted in Maringá with 50 students, demonstrated that the experimental group outperformed the control group. Figure 1 illustrates the comparative performance in formative assessments, highlighting a steeper learning curve for the experimental group.

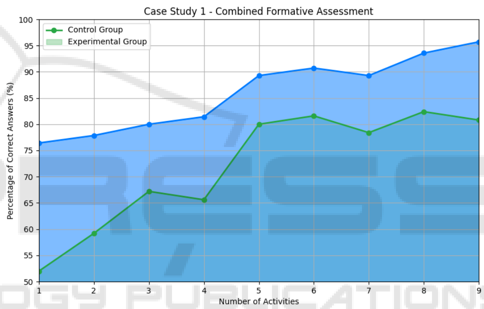

Figure 2: Performance of control and experimental groups in Case Study 1.

In the innovation competition, experimental teams achieved higher scores in originality and teamwork. These results suggest that team formation, guided by learning styles and socio-emotional competencies, positively influenced student performance.

4.3 Case Study 2

The second case study, conducted in Campo Mourão with 30 students, showed that the experimental group performed slightly better than the control group. Figure 2 presents the comparative performance in formative assessments.

In the innovation competition, experimental teams excelled in practical applicability and teamwork, emphasizing the adaptive methodology's effectiveness in fostering collaboration and viable solutions.

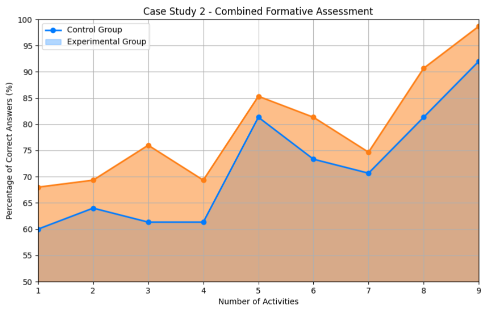

Figure 3: Performance of control and experimental groups in Case Study 2.

4.4 Case Study 3

The third case study, conducted in Cianorte with 78 students, revealed that although overall performance was similar, the experimental group showed a clear advantage in final activities, suggesting better concept retention. Figure 4 shows performance in formative assessments.

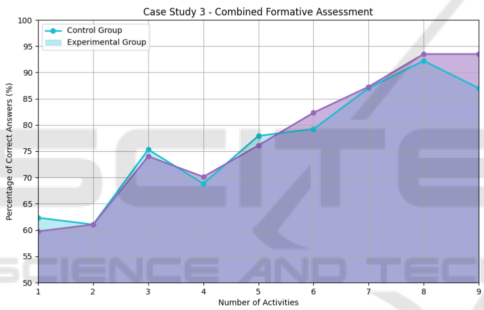

Figure 4: Performance of control and experimental groups in Case Study 3.

Experimental teams outperformed in applicability and teamwork during the innovation competition, indicating that the methodology rooted in learning styles and socio-emotional competencies offers additional benefits.

4.5 Case Study 4

The fourth case study, conducted in Paranavaí with 37 students, demonstrated a pronounced difference between the experimental and control groups, with the experimental group outperforming in all activities. Figure 5 compares group performance in formative assessments.

During the innovation competition, experimental teams attained the highest scores across all evaluated criteria, as shown in Table 2.

Results indicate that teams in the experimental group excelled in all criteria, suggesting that the personalized methodology had a significant impact on student performance.

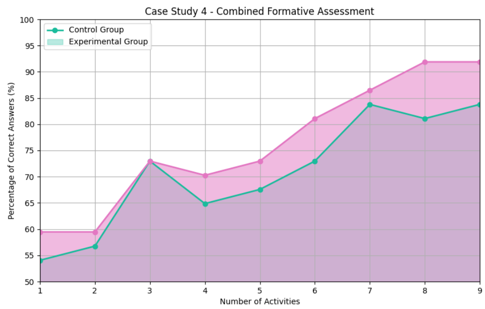

Figure 5: Performance of control and experimental groups in Case Study 4.

4.6 Variability of Results

To analyze the variability of results between the experimental and control groups, we used boxplot graphs illustrating performance distribution in each activity. Figure 6 presents the boxplots of formative assessment scores for both groups across the nine activities.

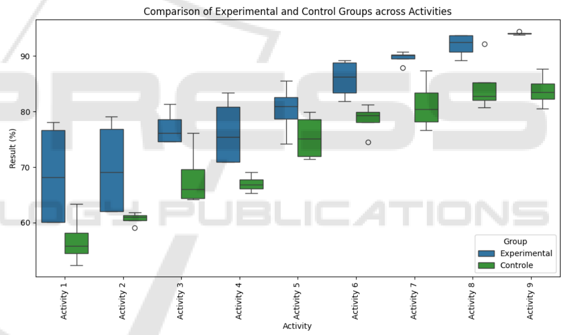

Figure 6: Performance distribution of control and experimental groups.

It can be observed that experimental groups tend to have higher medians in the activities, as well as less data dispersion, indicating more consistent performance. Control groups show greater variability in results, with some activities presenting significantly lower scores.

This chart visually consolidates the positive impact of the personalized methodology on student performance, showing that the intervention resulted in more stable and superior performance in the experimental group.

4.7 Summary of Results

The results of the four case studies reinforce the effectiveness of the personalized methodology based on learning styles and socio-emotional competencies.

Table 2: Team Scores in the Innovation Competition – Case Study 4.

Team	Originality	Applicability	Technical Complexity	Teamwork	Presentation
Team 1 (Exp)	9.5	9.0	8.5	9.0	9.0
Team 2 (Exp)	9.0	8.5	8.0	8.5	8.5
Team 3 (Ctrl)	8.0	7.5	7.0	7.5	7.5
Team 4 (Ctrl)	7.5	7.0	6.5	7.0	7.0

The experimental group demonstrated superior or equivalent performance to the control group, with notable improvements in collaboration and practical applicability in the innovation competitions. These findings support the hypothesis that classifying students based on learning styles and socio-emotional competencies promotes superior academic performance and personal development.

5 INTERPRETATION OF RESULTS

The results of the four case studies were analyzed considering the hypothesis and research questions, focusing on the impact of the personalized methodology—grounded in Kolb's learning styles and socio-emotional competencies—on students' academic performance and personal development. Personalizing instruction through clustering based on these styles, facilitated by the K-means algorithm, emerged as a promising approach. Experimental groups consistently outperformed control groups across various criteria, as detailed in Section 4.

Student satisfaction was measured by categorizing testimonials into satisfied, neutral, and dissatisfied, with scores of 5, 3, and 1, respectively. Based on 117 testimonials (99 satisfied, 18 neutral, 0 dissatisfied), the average score was 4.69 on a scale of 1 to 5, indicating a high overall satisfaction level.

5.1 Hypothesis Confirmation

The central hypothesis—that grouping students based on learning styles and socio-emotional competencies enhances academic performance and personal development—was confirmed. Quantitative data demonstrated that experimental groups consistently outperformed control groups in originality, practical applicability, teamwork, and technical complexity. This superiority was further supported by testimonials, with 84.6% of students reporting high satisfaction.

5.2 Research Questions

Q1: How do IoD bootcamps influence the development of students' technical skills? The bootcamps offered a hands-on environment emphasizing theory application, as reflected in high scores for technical complexity and practical applicability. Challenging activities like programming and piloting encouraged meaningful learning.
Q2: In what ways do IoD bootcamps impact participants' socio-emotional competencies? Experimental groups exhibited stronger communication, collaboration, and conflict resolution skills, underscoring the methodology's positive impact on socio-emotional development.
Q3: What is the effect of personalized teaching on students' academic performance? Personalized instruction enhanced content assimilation, as evidenced by steeper learning curves in formative assessments. Clear explanations and consistent support were pivotal to student success.
Q4: What are the differences in skill development between experimental and control groups? Experimental groups showed superior performance in nearly all criteria, except originality, where some control teams also excelled, suggesting that originality may be influenced by other factors.
Q5: How do students perceive the effectiveness of IoD bootcamps? Perception was largely positive, with 84.6% expressing full satisfaction. Practical activities were a highlight, though some mentioned difficulties with programming and limited practice time.

5.3 Variability of Results

The smaller performance difference in Case Study 3 suggests that contextual factors, such as participant characteristics and educational environment, may influence the methodology's effectiveness, indicating a need to adapt implementation to different contexts.

While experimental groups outperformed control groups in practical applicability and teamwork, some control teams excelled in originality, suggesting that creativity and innovation may not be entirely linked to strategic formation based on learning styles and socio-emotional competencies.

5.4 Study Limitations

Study limitations include variations in sample sizes and contextual factors, such as student motivation and limited practice time, which may have influenced the results. Some students reported challenges with programming activities, citing insufficient time for practice, which could have impacted overall perceptions.

Nevertheless, teaching personalization based on Kolb's learning styles and socio-emotional competencies was positively highlighted, enhancing academic performance and socio-emotional development. Future studies may explore how this personalization, combined with active methodologies and innovative technologies, can maximize student competency development.

6 CONCLUSION

This study demonstrates that combining a methodology grounded in learning styles and socio-emotional competencies, as applied in Internet of Drones (IoD) Bootcamps, yields positive outcomes. Personalized instruction, paired with strategic team formation, proves effective in enhancing technical skills and fostering collaborative competencies.

Experimental groups consistently outperformed control groups in formative assessments and innovation competitions, particularly excelling in practical applicability and teamwork. The integration of drones and exponential technologies created an immersive experience, enhancing the assimilation of complex concepts and promoting creativity.

Qualitative testimonials support these findings, highlighting students' satisfaction with the content, collaborative dynamics, and instructor support. An average satisfaction score of 4.69 (on a 1 to 5 scale) reflects a high level of acceptance for the methodology.

Despite promising results, the study highlights areas for improvement, including optimizing the time allocated for programming practices and accounting for the specific characteristics of participants across different educational contexts. Variability in results suggests that the methodology's effectiveness may depend on contextual and individual factors.

The integration of classical and active methodologies enriched the teaching-learning process. Continuous assessments conducted before, during, and after the activities enabled real-time adjustments, ensuring a more personalized and relevant experience. The use of exponential technologies, such as IoD, demonstrated strong potential to enhance the development of technical and socio-emotional skills, aligning with the principles of Education 5.0.

In the landscape of educational innovation, the Manna_Team distinguishes itself by advancing the integration of exponential technologies into learning environments. With a commitment to inclusion, sustainability, and personalization, Manna provides adaptive pedagogical approaches that equip students and teachers to tackle 21st-century challenges. Future studies should explore how these personalized methodologies can be refined and scaled across diverse contexts and populations to broaden their applicability.

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