Manna Methodology: An Unprecedented Approach to Education 5.0 in Learning and Socio-Emotional Assessment in the Context of IoD Bootcamps

T.T. Madrigar[1], R. Calvo[1], L.B. Ruiz Aylon[1]
[1]*Manna Ecosystem - State University of Maringá, BRAZIL*
tiago@madrigar.com.br, rcalvo@uem.br, lbruiz@uem.br

Keywords: Education 5.0, Exponential Technologies, Socio-emotional Skills, Internet of Drones (IoD), Imersive Bootcamps, Personalized Pedagogy, Machine Learning, Learning Styles, Artificial Intelligence, 21st Century Skills

Abstract: This study investigates the practical application of Education 5.0 through a methodology that integrates exponential technologies, with emphasis on the Internet of Drones (IoD), in the development of students' technical and socio-emotional competencies. Conducted within the Manna Ecosystem—the largest ecosystem for teaching, research, extension, and innovation in Exponential Technologies in Brazil—the study evaluated 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 INTRODUÇÃO

The digital transformation is redefining the way we live, work, and learn, dissolving the boundaries between online and offline into a new paradigm, which Floridi terms "onlife." In this condition, technology becomes deeply integrated into daily life, creating a new reality (Floridi, 2014). This scenario assigns education an expanded role in developing skills that go beyond technical knowledge, incorporating socio-emotional competencies essential for the contemporary context. In response to these transformations, Education 5.0 positions itself as an approach that combines technological advancements with a humanistic focus, fostering holistic formation and preparing individuals to face the complex challenges of the 21st century (Hussin, 2018). This educational perspective is not limited to keeping pace with technological innovation; rather, it seeks to apply exponential technologies, such as Artificial Intelligence (AI), the Internet of Things (IoT), and, notably, the Internet of Drones (IoD), to enrich learning experiences and promote personalization, protagonism, and collaboration in inclusive and interconnected educational environments, reflecting the onlife experience and addressing contemporary societal demands (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 happiness, 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 is based on two systematic literature reviews that provide a comprehensive view of the methodologies and technologies applied within the context of Education 5.0. The first review, titled *"Systematic Literature Review on Instruments and Strategies for Learning Assessment in the Context of Education 5.0"*, focused on methodologies and tools aimed at personalizing learning and integrating 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, titled *"Systematic Literature Review on Artificial Intelligence in the Context of Education 5.0"*, focused on the application of technologies like Artificial Intelligence (AI) and the Internet of Drones (IoD) in educational environments. This review initially identified 224 articles, from which 32 were pre-selected and 14 analyzed in the final stage. 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.

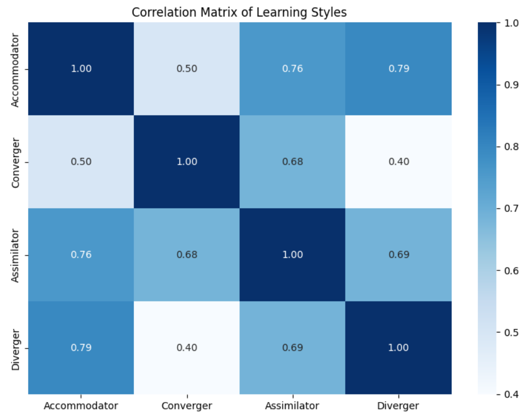

Figure 1: Correlation Matrix of Learning Styles

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

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.

2.4 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

In this section, we detail the study's methodology, including the context of the Internet of Drones (IoD) bootcamps held in four cities in Paraná; the teaching structure based on Kolb's learning styles and socio-emotional competencies; the application of the K-means algorithm for group formation; the assessment methods used (diagnostic, formative, and summative); cluster validation techniques; and ethical considerations..

The study was conducted in four cities in Paraná in January 2024, with 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). In each location, a case study was conducted following the same methodology.

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 chosen for its efficiency in grouping students based on quantitative characteristics such as learning styles and socio-emotional competencies (Hartigan et al., 1979), (Hamerly and Elkan, 2003). We applied K-means to maximize the diversity of learning styles within each team, fostering a collaborative 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 performed using *z-scores* (Felder, 2002), ensuring equal weight for all variables. The number of clusters was set to four, corresponding to Kolb's styles. We used the *k-means++* method to initialize the group formation process (Arthur and Vassilvitskii, 2007) and Euclidean distance as the similarity metric (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.

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 ensure impartiality and validity of the results, teachers were not informed in advance about the group formations, thereby minimizing biases during instruction. Evaluation was blinded, with evaluators unaware of which groups were experimental or control. Standardized assessment instruments ensured comparable 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).

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.

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

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

In this section, we present the results of the four case studies conducted in the cities of Maringá, Campo Mourão, Cianorte, and Paranavaí. We detail the inferential statistical analyses comparing the performance of the experimental and control groups, discussing the individual results of each case study, with a focus on formative assessment activities and innovation competitions. Key findings are highlighted regarding the effectiveness of the personalized methodology applied in 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.

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

Table 1: Evaluation Rubric for the Innovation Competition

4.1 Inferential Statistical Analyses

To assess the effectiveness of the methodology, we conducted inferential statistical analyses comparing the performance of the experimental and control groups. An independent t-test was used to compare the means of the two groups (Ruxton, 2006). Results indicated a statistically significant difference between the groups ($t(128) = 2.85$, $p < 0.05$), with the experimental group demonstrating superior performance. The calculated effect size ($d = 0.6$) was considered moderate to high, suggesting a relevant impact of the methodology (Cohen, 1988).

We also applied ANOVA to determine if sociodemographic variables, such as age and gender, influenced student performance (Montgomery, 2020). Results indicated no significant effects of these variables ($F(2,127) = 1.15$, $p = 0.32$), suggesting that the observed differences could mainly be attributed to the pedagogical methodology used.

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, showed that the experimental group outperformed the control group. Figure 2 compares the performance of the groups in formative assessments, showing that the experimental group had a steeper learning curve.

In the innovation competition, teams in the experimental group scored higher on criteria such as originality and teamwork. Results suggest that team formation based on learning styles and socio-emotional competencies positively influenced student performance.

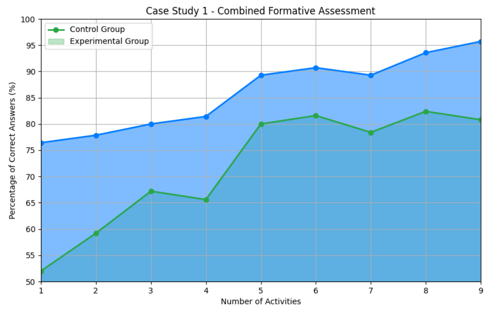

Figure 2: Performance of control and experimental groups in Case Study 1

4.3 Case Study 2

In the second case study, conducted in Campo Mourão with 30 students, the experimental group demonstrated slightly superior performance compared to the control group. Figure 3 illustrates performance in formative assessments.

In the innovation competition, experimental teams excelled in the criteria of practical applicability and teamwork, highlighting the effectiveness of the adaptive methodology in promoting collaboration and viable solutions.

4.4 Case Study 3

The third case study, conducted in Cianorte with 78 students, indicated that while overall group performance was similar, the experimental group showed an advantage in final activities, suggesting better retention of concepts. Figure 4 shows performance in

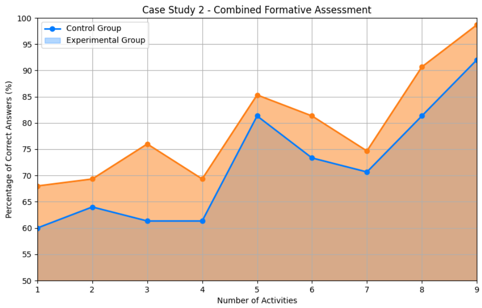

Figure 3: Performance of control and experimental groups in Case Study 2

formative assessments.

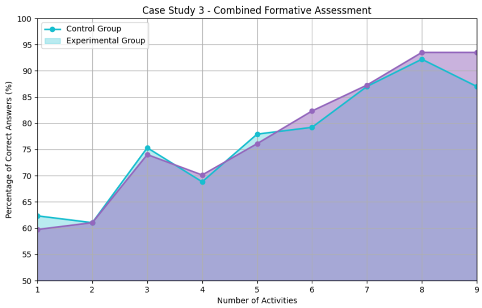

Figure 4: Performance of control and experimental groups in Case Study 3

Experimental teams excelled in the criteria of applicability and teamwork in the innovation competition, suggesting that the methodology based on learning styles and socio-emotional competencies may provide additional benefits.

4.5 Case Study 4

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

In the innovation competition, experimental teams achieved the highest scores in all evaluated criteria, as presented 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.

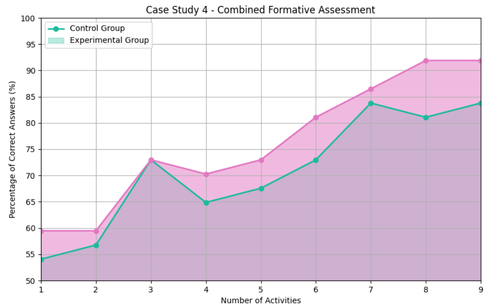

Figure 5: Performance of control and experimental groups in Case Study 4

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.

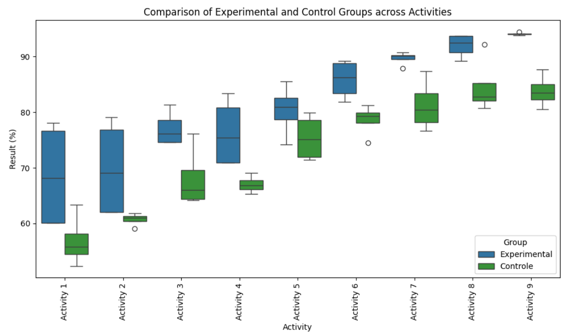

Figure 6: Performance distribution of control and experimental groups

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. The experimental group demonstrated superior or

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

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

We interpreted the results of the four case studies in light of the hypothesis and research questions, analyzing the impact of the personalized methodology, based on Kolb's learning styles and socioemotional competencies, on students' academic performance and personal development. Personalizing instruction through clustering based on these styles using the K-means algorithm (Hartigan et al., 1979) proved to be a promising approach, with the experimental groups outperforming the controls across various criteria, as discussed 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 classifying students based on learning styles and socio-emotional competencies would result in better academic performance and personal development—was confirmed. Quantitative data show that experimental groups consistently outperformed control groups in metrics such as originality, practical applicability, teamwork, and technical complexity. Testimonials reinforce this superiority, with 84.6% of students expressing high satisfaction.

5.2 Research Questions

Q1: How do IoD bootcamps influence the development of students' technical skills? The bootcamps provided a practical environment focused on applying theories, evidenced by high scores in technical complexity and practical applicability. Activities such as programming and piloting, although challenging, fostered meaningful learning.

Q2: In what ways do IoD bootcamps impact participants' socio-emotional competencies? Experimental groups demonstrated higher communication, collaboration, and conflict resolution skills, showing the positive impact of the methodology on socio-emotional development.

Q3: What is the effect of personalized teaching on students' academic performance? Personalization facilitated content assimilation, reflected in steeper learning curves in formative assessments. Support and clarity in explanations were essential to students' 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

Limitations include variation in sample sizes and contextual factors that may have influenced results, such as student motivation and available practice time. Some students found programming activities challenging and practice time short, which may have impacted overall perception.

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 suggests that the combination of the methodology based on learning styles and socioemotional competencies, applied in Internet of Drones (IoD) Bootcamps, yielded positive outcomes. Personalizing instruction, combined with strategic team formation, proved to be promising for developing technical skills and improving participants' collaborative competencies.

Experimental groups outperformed control groups in formative assessments and innovation competitions, excelling in practical applicability and teamwork. The use of drones and exponential technologies provided an immersive experience, facilitating the assimilation of complex concepts and fostering creativity.

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

Despite promising results, the study identified areas for improvement, such as adjusting the time allocated to programming practices and considering specific characteristics of participants in different educational contexts. The variability in results suggests that the effectiveness of the methodology may be influenced by contextual and individual factors.

The combination of classical and active methodologies enriched the teaching-learning process. Assessments conducted before, during, and after the activities allowed for adjustments along the way, providing a more personalized and relevant experience. The use of exponential technologies, like IoD, showed potential to enhance the development of technical and socio-emotional skills, aligning with the principles of Education 5.0.

In the educational innovation landscape, the Manna_Team stands out by promoting the use of exponential technologies in learning environments. With a focus on inclusion, sustainability, and personalization, Manna offers adaptive pedagogical approaches, preparing students and teachers for 21st-century challenges. Future studies could further investigate how these personalized methodologies can be optimized across different contexts and populations, expanding their applicability.

REFERENCES

Andrade, H. G. (2005). Teaching with rubrics: The good, the bad, and the ugly. *College Teaching*, 53(1):27–30.

Arthur, D. and Vassilvitskii, S. (2007). k-means++: The advantages of careful seeding. In *Proceedings of the Eighteenth Annual ACM-SIAM Symposium on Discrete Algorithms*, pages 1027–1035. Society for Industrial and Applied Mathematics.

Bennett, R. E. (2011). Formative assessment: A critical review. *Assessment in education: principles, policy & practice*, 18(1):5–25.

Black, P. and Wiliam, D. (2009). Developing the theory of formative assessment. *Educational Assessment, Evaluation and Accountability (formerly: Journal of personnel evaluation in education)*, 21:5–31.

Cohen, J. (1988). *Statistical Power Analysis for the Behavioral Sciences*. Lawrence Erlbaum Associates, Hillsdale, NJ, 2nd edition.

Cumming, G. (2012). *Understanding The New Statistics: Effect Sizes, Confidence Intervals, and Meta-Analysis*. Routledge, New York.

Dudek, A. (2020). Silhouette index as clustering evaluation tool. In *Classification and Data Analysis: Theory and Applications 28*, pages 19–33. Springer.

Felder, R. M. (2002). Learning and teaching styles in engineering education. *Engineering Education*, 78(7):674–681.

Floridi, L. (2014). *The Onlife Manifesto: Being Human in a Hyperconnected Era*. Springer, Cham.

Ford, M. (2021). *The Future of Learning: Redesigning the 21st Century Classroom*. Basic Books.

Halili, S. H. and Zainuddin, Z. (2015). Flipping the classroom: What we know and what we don't. *The online Journal of Distance Education and E-learning*, 3(1):15–22.

Hamari, J., Koivisto, J., and Sarsa, H. (2017). Does gamification work?–a literature review of empirical studies on gamification. *Procedia computer science*, 113:1101–1110.

Hamerly, G. and Elkan, C. (2003). Learning the k in k-means. *Advances in neural information processing systems*, 16.

Hartigan, J. A., Wong, M. A., et al. (1979). A k-means clustering algorithm. *Applied statistics*, 28(1):100–108.

Hussin, A. A. (2018). Education 4.0 made simple: Ideas for teaching. *International Journal of Education and Literacy Studies*, 6(3):92–98.

Jones, I., Brown, S., and Smith, E. (2020). The impact of rubrics on student performance and instructor feedback. *Journal of Educational Assessment*, 25(3):45–62.

Ketchen, D. J. and Shook, C. L. (1996). The application of cluster analysis in strategic management research: An analysis and critique. *Strategic Management Journal*, 17(6):441–458.

Kirschner, P. A. (2017). Stop propagating the learning styles myth. *Computers & Education*, 106:166–171.

Kolb, A. Y. and Kolb, D. A. (2005). Learning styles and learning spaces: Enhancing experiential learning in higher education. *Academy of management learning & education*, 4(2):193–212.

Luckin, R., Holmes, W., Griffiths, M., and Forcier, L. B. (2016). *Intelligence Unleashed: An Argument for AI in Education*. Pearson Education.

Manolis, C., Burns, D. J., Assudani, R., and Chinta, R. (2013). Assessing experiential learning styles: A methodological reconstruction and validation of the kolb learning style inventory. *Learning and individual differences*, 23:44–52.

Mayer, J. D. (2002). Msceit: Mayer-salovey-caruso emotional intelligence test. *Toronto, Canada: Multi-Health Systems*.

Montgomery, D. C. (2020). *Design and Analysis of Experiments*. John Wiley & Sons, 10th edition.

Neubauer, A. C. and Freudenthaler, H. H. (2005). Models of emotional intelligence. *Emotional intelligence: An international handbook*, 2005:31–50.

Nicol, D. J. and Macfarlane-Dick, D. (2006). Formative assessment and self-regulated learning: A model and seven principles of good feedback practice. *Studies in higher education*, 31(2):199–218.

Pashler, H., McDaniel, M., Rohrer, D., and Bjork, R. (2008). Learning styles: Concepts and evidence. *Psychological Science in the Public Interest*, 9(3):105–119.

Piaget, J., Cook, M., et al. (1952). *The origins of intelligence in children*, volume 8. International Universities Press New York.

Popenici, S. A. and Kerr, S. (2017). Exploring the impact of artificial intelligence on teaching and learning in higher education. *Research and Practice in Technology Enhanced Learning*, 12(1):1–13.

Ruxton, G. D. (2006). The independent-samples t-test. *Behavioral Ecology*, 17(4):688–690.

Salmon, G. (2019). Digital education: Opportunities for social cooperation and development. *British Journal of Educational Technology*, 50(2):271–286.

Salovey, P. and Mayer, J. D. (1990). Emotional intelligence. *Imagination, cognition and personality*, 9(3):185–211.

Torres, G., Ali, R., and Goh, D. (2019). Transforming education through technology: Challenges and possibilities. *International Journal of Educational Technology in Higher Education*, 16(1):1–15.

Vygotsky, L. S. and Cole, M. (1978). *Mind in society: Development of higher psychological processes*. Harvard university press.

Wang, F. and Hannafin, M. J. (2014). Design-based research and technology-enhanced learning environments. *Educational technology research and development*, 53(4):5–23.

Winsler, A., Kim, Y. K., and Richard, E. R. (2014). Socio-emotional skills, behavior problems, and spanish competence predict the acquisition of english among english language learners in poverty. *Developmental psychology*, 50(9):2242.

World Economic Forum (2020). Schools of the future: Defining new models of education for the fourth industrial revolution. Technical report, World Economic Forum, Geneva, Switzerland. Accessed: 2024-09-20.

Xu, Z., Chen, X., and Chen, Y. (2018). Educational robots for 21st century skills: A review. *Educational Review*, 70(4):456–473.