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Leveraging adaptive learning technology in TVET

A data-driven adaptive learning platform to personalize instruction at scale in industrial TVET courses

Promising Practice

Implemented by: National Service for Industrial Training (SENAI)

Where: Brazil

Status: January 2020 – December 2023

Summary: The initiative implemented adaptive learning technology to personalize instruction at scale using real-time learner data and artificial intelligence.

Education 2030

Overview

Technological and social transformations are reshaping the future of jobs, increasing demand for technological skills alongside human competencies, such as creative thinking and interpersonal skills. In this context, technical and vocational education and training (TVET) plays an important role in addressing changing skills needs.

In Brazil, TVET is offered within basic and higher education. While the Ministry of Education (MEC) establishes national education policies and guidelines, TVET is delivered by a range of providers, including public and private institutions, and the S-System (Sistema-S). Established in 1942, the National Service for Industrial Training (SENAI) is part of the S-System, and it operates as one of the largest training networks in Latin America.

The integration of digital learning technologies into TVET offers opportunities to personalize instruction while taking into account the practical nature of vocational training. Against this backdrop, SENAI implemented an adaptive learning initiative in selected industrial TVET courses between 2020 and 2023, using real-time learner data and artificial intelligence to personalize instruction at scale.

Description

The initiative targeted students enrolled in strategic industrial technical courses: Mechanics, Industrial Automation and Mechatronics. It aimed to address the challenges of managing classes of 25-30 students with different learning paces, where a single instructor needs to respond to diverse learning needs.

The blended learning model developed by SENAI combined the flexibility of an intelligent adaptive virtual environment with in-person workshop activities.

The adaptive platform enabled the personalization of theoretical-cognitive learning, while practical laboratory activities focused on Problem-Based Learning (PBL) and real-world professional simulation, supporting the development of students' cognitive, socio-affective and psychomotor domains.

This data-driven system uses artificial intelligence and machine learning to capture students' actions, behaviours and performance patterns in real time, generating individual predictive models of competence. Functioning as an Intelligent Tutoring System (ITS), it provides immediate support, personalized direct instructions and specific feedback for each knowledge domain.

Every click, response time, error type or solution attempt is captured, allowing the algorithm to analyse the data through the lens of a student's cognitive model. Based on this, the system makes immediate, autonomous pedagogical decisions, adjusting the visual presentation of concepts, calibrating the pace, refining the level of difficulty and reordering the sequence of future lessons. This process allows teachers to act strategically through automated progress reports.

If a student demonstrates ease with a complex industrial electricity item, for example, the system removes scaffolding and accelerates the path toward the learning goal. If they demonstrate difficulty, the intelligent tutor intervenes, presenting intermediate explanations, altering the pedagogical media and inserting diagnostic questions. For instructors, the solution included analytical dashboards on student performance - both at the individual and aggregate levels -providing real-time insights and enabling adjustments to lesson planning to support the full development of professional competencies.

Objectives

The primary objective of this initiative is to personalize instruction and support the development of cognitive, socio-affective and psychomotor skills among students enrolled in strategic industrial technical courses.

Outcomes and impact

To assess learning outcomes, SENAI used standardized Evaluation Reference Matrices. These matrices define the professional skills and competencies students are expected to demonstrate in solving real-world problem situations.

At the end of the training, students in both the adaptive and traditional learning groups completed two assessments: a theoretical knowledge test and a practical test focused on Problem-Based Learning (PBL).

- Objective Test: Consisted of 40 multiple-choice items. Balanced Incomplete Block Design (BIBD) and Item Response Theory (IRT) to support comparability of test scores.
- Practical Test: Composed of one or more PBL situations. Students were placed in practical challenges in SENAI's workshops such as detecting a fault in an industrial automation electrical panel, calibrating a mechanical assembly or programming a mechatronic arm. Performance was recorded by certified evaluators using standardized observational guides[1].
- The results of these two types of assessment are analysed using modern evaluation techniques, which are translated into qualitative and quantitative data. This enables educators to identify strengths and specific areas of potential, providing feedback for educational planning and pedagogical practice with a focus on continuous improvement.

Quantitative results and performance trends

The analysis covers results from 2020 to 2023 for 23,409 students across SENAI schools: 3,569 students in the Adaptive Group, who used the intelligent platform for theoretical learning, and 19,840 in the Traditional Group, who followed face-to-face teaching without dynamic personalization. Performance was measured on a scale from 0 to 10.

[1] Serviço Nacional de Aprendizagem Industrial [SENAI] (2021). Elaboração de Itens. Diretoria de Educação e Tecnologia, Brasília.

Table 1: Mean final performance results in the objective test (Scale 0-10)

Year	Automation (Adapt.)	Automation (Trad.)	Mechanics (Adapt.)	Mechanics (Trad.)	Mechatronics (Adapt.)	Mechatronics (Trad.)
2020	-	-	8	7.5	-	-
2021	6.8	5	8.2	7.5	8	7.5
2022	6	5.2	8.2	8	7.5	6.5
2023	6.2	6.2	7.5	7.8	7.2	7.5

Table 2: Mean final performance results in the practical test (Scale 0-10)

Year	Automation (Adapt.)	Automation (Trad.)	Mechanics (Adapt.)	Mechanics (Trad.)	Mechatronics (Adapt.)	Mechatronics (Trad.)
2020	-	-	8.9	8.2	-	-
2021	8.1	7.6	8.8	7.4	10	9
2022	7.6	7.7	7.7	6.5	7.5	7.9
2023	8.9	9	8.3	8.1	8.7	8.9

In the objective tests, the Adaptive Group obtained higher average scores in all available course comparisons for 2020-2021. In Industrial Automation in 2021, the average was 6.80 compared with 5.00 for the Traditional Group. In Mechanics, this advantage remained steady for three years (2020-2022). In Mechatronics, it was 8.00 compared with 7.50 in 2021 and 7.50 compared with 6.50 in 2022.

However, the 2023 results were mixed: In industrial Automation both groups tied at 6.20 points, while the Traditional Group had slightly higher averages in Mechanics (7.80 vs 7.50) and Mechatronics (7.50 vs 7.20).

Although SENAI's adaptive learning platform focused on theoretical learning rather than physical training, the Adaptive Group also achieved higher practical test scores in some courses and years. This suggests that personalized theoretical learning may complement in-person practical training.

Gender-related findings

The sample was reported as 88% male, 11% female and 1% did not identify themselves. Female students in the Adaptive Group achieved higher average scores than those in the Traditional Group across all three courses: Mechatronics (7.05 vs 6.78), Industrial Automation (6.24 vs 5.29) and Mechatronics (7.05 vs 6.26).

Insights and challenges

The implementation highlighted three challenges: access to digital infrastructure, the cost and complexity of adaptive learning systems, and the changing role of teachers.

- Digital divide: School digitalization risks excluding students who lack technological infrastructure at home. SENAI responded by adopting the blended learning format and making digital tools accessible through school libraries and computer labs.
- Cost and resources: Adaptive ecosystems require investment in software licensing and qualified staff to encode cognitive maps, design digital educational resources and calibrate machine learning engines for different technical areas.

- Teacher support: Adaptive learning technologies should expand rather than replace the educator's role. SENAI's platform provided teachers with learning analytics dashboards, which identified students who were struggling and the topics that required extra attention. This allowed teachers to focus on targeted support.

Conclusion and next steps

SENAI's adaptive learning initiative offers a large-scale example of combining personalized theoretical learning with face-to-face practical training in industrial TVET. The four-year evaluation (2020–2023), covering more than 23,000 students, showed encouraging results in several courses and years, including positive outcomes among female students. The practice highlights the potential of data-driven adaptive learning to support personalized instruction in TVET at scale. Proposed next steps include expanding adaptive cognitive modelling to other industrial sectors, such as food, chemistry and civil construction, further integrating generative AI conversational assistants and improving continuous teacher training in data-driven instruction.

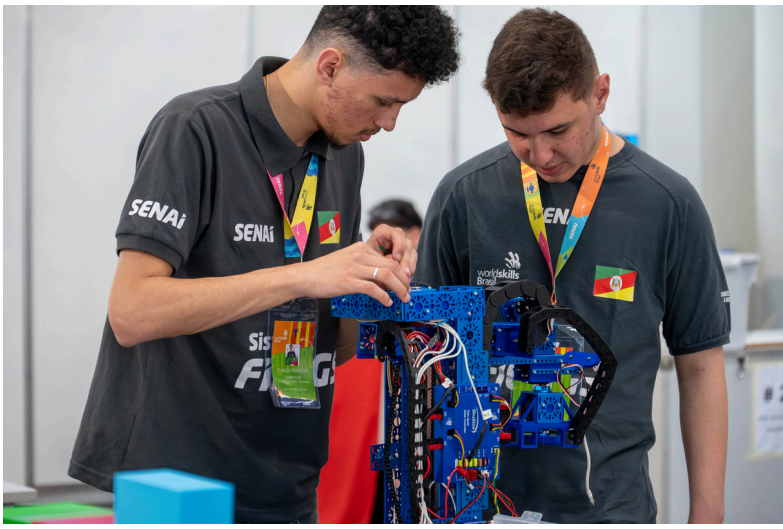


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