A long-term intervention in primary education to secure equality in the workforce: preliminary results from AutoSTEM

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Abstract: The Erasmus+ AutoSTEM project implements an educational intervention to introduce automation and control concepts using physical robotics kits and digital simulators. This paper outlines the motivation for the project, which aims to secure equality in the workforce by closing the persistent gender gap in STEM fields among high school students. While empirical evaluation is currently ongoing, this article details the pedagogical methodology and the expected results that will be presented at the conference.

Keywords: automatic control; STEM education; robotics.

1. INTRODUCTION

The global economy is navigating a transition towards Industry 5.0, which heavily relies on a workforce highly skilled in cyber-physical systems, collaborative robotics, and advanced industrial automation. Despite this growing global demand, there is a persistent and troubling gap between early student interest in STEM subjects and the pursuit of technical careers, affecting female students in a larger scale. To effectively introduce high school students to STEM careers and reverse these trends, educational curricula in secondary schools must include authentic, inquiry-based learning activities (Huyer, L.D., *et al.*, 2020). Furthermore, students in higher education often struggle with theoretical mathematics and control concepts because it feels abstract, disconnected from real-world applications, and difficult to visualize, which leads to students in Engineering programs deprioritizing automatic control courses.

Integrating the theoretical foundations of automatic control, robotics and programming with tangible, real-world technological applications help bridge the gap between abstract theory and practice, making engineering principles significantly more intuitive and engaging. Furthermore, closing the gender gap requires actively overcoming systemic barriers that might hinder female students from pursuing STEM careers. Research highlights that a lack of exposure to female role models, prevailing gender stereotypes, and the "impostor phenomenon" severely diminish female students' self-efficacy and lead to a rejection of scientific and technological fields. Addressing this requires dedicated interventions based on Maker Education and hands-on learning. Iterative, problem-based learning models delivered in senior high schools have been proven to enhance students' critical thinking, stimulate persistence, and improve academic performance, particularly for students that may become disillusioned by traditional knowledge-focused learning approaches (Hernández-Pérez, M. *et al*, 2024; Sápi, J. *et al.*, 2025).

The Erasmus+ AutoSTEM project (Project Number: 2025-1-IT02-KA210-SCH-000358066) addresses these educational needs by deploying a targeted intervention in Italy and Sweden to make robotics, automatic control and programming accessible, engaging, and inclusive.

2. PROCEDURE AND METHODOLOGY

AutoSTEM is driven by a consortium comprising Optimation AB, ANcybernetics, and Università Politecnica delle Marche. We combine academic pedagogical knowledge, educational robotics and practical industrial insights is order to develop educational materials for high-school students and facilitators. The educational program is structured around a comprehensive 6-hour workshop, divided into three components: two hours of theoretical foundations, two hours of virtual simulation, and two hours of hands-on robotic practice. To provide an authentic technological experience, the project utilizes M5Stack's BalaC[1], a self-balancing Segway-type robot. Students program the robot's logic using the block-based UIFlow integrated development environment. Before deploying code to the physical hardware, students use B.R.I.D.G.E. to simulate the robot. This allows students to get familiar with UIFlow and to safely test and calibrate Proportional-Integral-Derivative (PID) controller parameters. Along the technical implementation, the curriculum explicitly teaches the four cornerstones of computational thinking: decomposition, pattern recognition, abstraction, and algorithmic design.

3. MOTIVATION AND EXPECTED RESULTS

The primary motivation driving the AutoSTEM project is the need to secure workforce equality by actively mitigating gender stereotypes in engineering and technology. By bringing high-quality, cost-effective robotics education to secondary classrooms, the project aims to shed light on what professionals in the robotics and automatic control fields work with.

While the pilot workshops are currently in the implementation phase and final data is not yet available, the expected results

[1] https://shop.m5stack.com/products/bala-c-plus-esp32-self-balancing-robot-kit

will be presented at the conference. The evaluation methodology utilizes pre- and post-intervention questionnaires designed with 5-point Likert scales, grounded in Social Cognitive Career Theory. The questionnaires are available in Appendix A. At the time of writing, we have 6 workshops planned in Sweden and 1 workshop planned in Italy, with high school students between 15 and 17 years old. In some cases, we will have to shorten the workshop to comply with time constraints and student availability. After collecting and analyzing the questionnaires, we expect to present and discuss:

- A measurable, statistically significant increase in female students' interest in pursuing STEM-related activities and careers.
- Positive shifts in domain-specific self-efficacy, specifically regarding students' confidence in their ability to tune a PID controller, effectively counteracting the impostor syndrome.
- Confirmation that the integration of digital tools such as simulators and robots reduces the perceived difficulty of control systems engineering for adolescent learners.

4. CONCLUSIONS

This paper has outlined the structural methodology and driving motivations behind the AutoSTEM project. By actively introducing real-world automation concepts through interactive robotics, the intervention seeks to decrease gender barriers and the impostor syndrome in secondary education. The expected results, to be presented at the forthcoming conference, will offer insights on equitable, inquiry-based STEM education strategies across Italian and Swedish school systems.

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DECLARATION OF GENERATIVE AI AND AI-ASSISTED TECHNOLOGIES IN THE WRITING PROCESS

During the preparation of this work the author(s) used Google's NotebookLM for literature review and creation of the first draft. After using this tool/service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the publication.

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Appendix A. PRE-POST QUESTIONNAIRE

Pre questionnaire

1. Demographics

Age: _____

Gender:
☐ Male

☐ Female

☐ Non-binary/other

☐ Prefer not to say

Course year: _____

2. Background Experience

Do you have experience in:

Robotics
☐ Yes ☐ No

Automatic Control
☐ Yes ☐ No

Programming
☐ Yes ☐ No

Serious game (simulator)
☐ Yes ☐ No

3. Video Game Usage

How much time do you spend on average playing video games?

Consider mainly consoles and PC.

Weekdays:
☐ Less than 1 hour
☐ 1–2 hours
☐ 2–4 hours
☐ More than 4 hours

Weekend:
☐ Less than 1 hour
☐ 1–2 hours

☐ 2–4 hours
☐ More than 4 hours

All the questions below are evaluated in a 5-point Likert scale where:
1 = Strongly disagree | 2 = Disagree | 3 = Neutral | 4 = Agree | 5 = Strongly agree

4. Perceptions about Robotics and Control

I feel capable of understanding basic concepts of robotics

I feel capable of following an explanation about robotic systems even if the topic is new

I feel capable of applying robotics concepts in simple practical activities or simulations

I feel able to explain what a control system is

I feel able to explain how a PID controller works

I feel able to understand system behavior by changing P, I, D

I believe that studying robotics can be useful for my future

5. Interest

I am interested in topics related to automatic control

I am interested in robotics

I am interested in STEM (Science, Technology, Engineering, or Mathematics) subjects

I am interested in a career related to STEM (Science, Technology, Engineering, or Mathematics) fields

6. Expectation

I think the activities will be engaging

I think the planned activity will help me better understand concepts related to automatic control

I think the activity will be challenging but manageable

I think the serious game (simulator) will be easy to use

I think the serious game (simulator) will help me better understand concepts of control and PID

I think learning with a serious game (simulator) will be more interesting than a traditional lesson

All the questions below are evaluated as 1= correct | 0 = not correct

7. Knowledge

A serious game (simulator) is:
☐ A game designed only for entertainment
☐ A game designed for educational or training purposes
☐ A video game with advanced graphics
☐ A game that requires physical activity

The main purpose of a control system is:
☐ To increase energy consumption
☐ To regulate a system to reach a desired output
☐ To make systems more complex
☐ To eliminate all disturbances completely

What does PID stand for?
☐ Proportional Integral Derivative
☐ Process Input Data
☐ Power Integrated Device
☐ Proportional Internal Difference

A PID controller uses:
☐ Only proportional action
☐ Only integral action
☐ Proportional, integral, and derivative actions
☐ Random adjustments based on system noise

What is meant by autonomous motion of a vehicle?
☐ Movement controlled manually by a human operator
☐ Movement that follows a predefined path without reacting to the environment
☐ Movement that is controlled by onboard systems using sensor feedback without human intervention
☐ Movement that is always random and unpredictable

Post questionnaire

1. Demographics

Age: _____

Gender:
☐ Male

☐ Female

☐ Non-binary/other

☐ Prefer not to say

Course year: _____

All the questions below are evaluated in a 5-point Likert scale where:
1 = Strongly disagree | 2 = Disagree | 3 = Neutral | 4 = Agree | 5 = Strongly agree

2. Perceptions about Robotics and Control

Same questions as in pre-questionnaire.

3. Interest

Same questions as in pre-questionnaire.

4. Expectation

I think the activities were engaging

I think the planned activity helped me better understand concepts related to automatic control

I think the activity was challenging but manageable

I think the serious game (simulator) was easy to use

I think the serious game (simulator) helped me better understand concepts of control and PID

I think learning with a serious game (simulator) was more interesting than a traditional lesson.

5. Knowledge

Same questions as in pre-questionnaire.

6. Open-ended questions

What worked well during the activity?

What did not work well? Suggestions?

What is something interesting you learned?