

WORKING PAPER

Developing Applied STEM and Digital Skills in Lebanon

Findings from Implementation Research

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Executive summary

Over half of 15-year-olds did not meet the minimum proficiency level in science (54.5 per cent) or mathematics (55.7 per cent) in the 2022 Programme for International Student Assessment (PISA). These results reflect prolonged school disruptions and significant learning losses due to the economic crisis, COVID-19 closures, and period of instability. These challenges have been compounded by system-wide constraints, including reduced instructional time and limited resources

Strengthening girls' and boys' skills in science, technology, engineering and mathematics (STEM) is essential for developing students' ability to understand new technologies, think creatively, and adapt to evolving academic and career pathways, laying the foundation for future participation in technology-driven sectors. Through hands-on STEM learning, students can develop various transferable skills such as critical thinking, collaboration and problem-solving. More broadly, STEM education can also support innovation and provide solutions to global challenges, such as clean energy, health.

To help address these gaps, the United Nations Children's Fund (UNICEF), in coordination with Lebanon's Ministry of Education and Higher Education, implemented a 16-week STEM pilot programme in 25 public schools across eight governorates. The schools were selected in coordination with the Ministry, and the programme was implemented in partnership with CodeBrave and with funding from the German Government through KfW Development Bank. The programme targeted students in Grades 6 to 9 during the last semester of the 2024/25 school year, across morning and afternoon school shifts. It aimed to build students' and teachers' coding skills and strengthen their problem-solving abilities, to introduce robotics through practical applications and to reduce the gaps between girls and boys in digital skills.

A total of 3,012 students took part in the inception programme (57 per cent female). Implementation research was embedded in the delivery of the programme to examine programme delivery in public school settings, to estimate the programme's effectiveness in enhancing technical skills, and to assess the potential for sustainable teacher-led implementation in the future. Key findings and recommendations are outlined below.

Key findings



1. The STEM programme significantly improved students' and teachers' coding skills.

- Students' test scores increased markedly from 1.3/10 at the pre-test to 7.8/10 at the post-test. Schools with strong engagement from the principal, better access to devices and fewer strike-related disruptions achieved stronger results.
- Using a Propensity Score Matching model, the estimates show students who participated in the programme scored nearly 6.5 points higher on the 10-point post-test than students matched with similar attributes who were not enrolled. This indicates that learning gains were attributable to participation in the programme. The similar levels of scores at the pre-test for the treatment group and the scores at post-test for the comparison group suggest that the skills taught in the programme are normally not taught in participating schools.

- Teachers also demonstrated substantial improvement, with average scores rising from 4.33/16 at the pre-test to 9.93/16 at the post-test. Higher gains were achieved among teachers who had prior experience integrating digital learning (11.5/16 compared with 8.4/16 at the post-test).



2. Students' self-efficacy, motivation and broader learning skills increased, with confidence gaps between boys and girls narrowing.

- Students had higher confidence and enjoyment in coding after the programme. Pre-existing gaps between girls and boys in self-efficacy diminished by the end of the course.
- Focus groups showed gains beyond coding, including in critical thinking, persistence and collaborative problem-solving abilities, which are transferrable skills.
- The programme sparked further interest in other subjects, such as English and physics, as students understood their importance in programming. For example, English is necessary for understanding coding terms, and physics for applying concepts like temperature measurement.



3. The programme was positively received, with many girls reporting a new interest in pursuing STEM-related fields.

- Students, teachers and principals reported strong satisfaction with the programme. A key contributing aspect was the course's practical, hands-on and engaging approach, which made learning feel fun, dynamic and inspiring.
- Both boys and girls enjoyed projects on micro:bits, AgriTech and coding kits, with content linked to real-life applications, such as agriculture, automation and environmental problem-solving.
- Many girls reported an increased interest in STEM career pathways, while boys reinforced their existing STEM aspirations. Principals agreed the programme strengthened students' employability and practical skills for the future.



4. Key implementation challenges included course and session length, limited existing familiarity with technology and a lack of devices in some schools (likely to be linked with larger class sizes).

- Students, especially girls, reported that the course moved quickly and short lessons left limited time to absorb new concepts and complete hands-on activities.
- Many students had limited prior experience with coding and laptops, according to teacher insights, and this posed challenges early in the programme.
- Programme delivery was affected by insufficient numbers of devices in some schools, large class sizes and a lack of familiarity with English terminology, as well as technical interruptions such as electricity outages, internet problems and equipment failures.

Recommendations



1. Align course scheduling with the Ministry of Education and Higher Education and school timetables to ensure sufficient session length and continuity.

- Identify suitable time slots within the school timetable, ensuring that the course begins early in the school year to provide continuity and a manageable workload for teachers.
- Allocate sessions with a duration and frequency that allows students to absorb content, complete hands-on activities and build skills progressively.



2. Strengthen teacher capacity through sustained training, coaching and incentives.

- Provide intensive initial training followed by ongoing, in-school coaching to reinforce teacher confidence and independence.
- Use scenario-based practice and hands-on demonstrations to build both technical mastery and effective classroom management, including differentiated support and scaffolding.
- Align the course with teacher career pathways, fair compensation and recognition to sustain motivation.



3. Ensure school-level readiness, leadership engagement and adequate classroom resources.

- Engage school principals early to secure buy-in, strengthen monitoring of teacher-led implementation and ensure alignment with the broader curriculum.
- Provide teachers with ready-made lesson plans and technical support.
- Manage class size and groupings to ensure appropriate student-to-device ratios, and strengthen systems for equipment storage, access and classroom management.



4. Include preparatory modules on basic computer literacy and terminology, while expanding the real-world relevance of the programme.

- Offer preparatory foundational training for students in basic computer use, coding principles and essential English vocabulary, to facilitate understanding of course content.
- Further embed real-world applications within the programme curriculum to enhance engagement, relevance and motivation for both students and teachers.

1. Introduction

Over half of 15-year-olds did not meet the minimum proficiency level in science (54.5 per cent) or mathematics (55.7 per cent) in the 2022 Programme for International Student Assessment (PISA).¹

Strengthening girls' and boys' skills in science, technology, engineering and mathematics (STEM) is essential for developing students' ability to understand new technologies, think creatively, and adapt to evolving academic and career pathways, laying the foundation for future participation in technology-driven sectors.² Through hands-on STEM learning, students can develop various transferable skills such as critical thinking, collaboration and problem-solving.³ More broadly, STEM education can also support innovation and provide solutions to global challenges, such as clean energy, health.⁴

In response to these learning gaps, the United Nations Children's Fund (UNICEF) and Lebanon's Ministry of Education and Higher Education, in coordination with the Lebanese non-profit organization CodeBrave, and with funding from the German Government through the KfW Development Bank, implemented a STEM pilot programme during the 2024/25 school year. The programme was targeted at students in Grades 6 to 9 across 25 public schools in eight governorates and aimed to:

1. introduce students to STEM education and robotics in an inclusive manner ensuring to address equity between girls and boys, assess their interest and learning gains, and build foundational coding skills to support the creation of technology solutions to real-world problems;
2. assess the readiness and engagement of teachers and principals to integrate STEM education into teaching and learning; and
3. identify best practices and challenges to inform the future scale-up of the integration of STEM education in public schools.

Annex 1 includes the full list of key competencies and skills that the programme targeted.

The programme ran for 16 weeks, with 14 weeks dedicated to content delivery, and the first and final weeks reserved for pre-testing and post-testing for students and teachers. Some schools experienced teacher strikes during implementation, which required adjustments to scheduling. Sessions lasted 45–60 minutes (reduced to 40 minutes during Ramadan) and were facilitated by CodeBrave educators, while school teachers shadowed the sessions to learn how to deliver STEM activities independently in subsequent years.

The programme's curriculum was designed to progressively build students' technical and problem-solving abilities through hands-on, real-world applications. Each school received 20 micro:bit devices, 8 AgriTech kits and 15 laptops. Key components included:

- **Foundational coding:** Creating simple games using Scratch to introduce events, loops, variables and conditionals.
- **Physical computing:** Using micro:bit devices and AgriTech kits to make prototype solutions to agricultural challenges, such as crop-height measurement, temperature and heating monitors, auto-irrigation devices and smart light/shade systems.
- **Artificial intelligence (AI) and machine learning:** Training simple machine learning models to introduce basic AI concepts.

Teachers completed a 12-hour orientation prior to implementation, delivered by CodeBrave, to familiarize them with the objectives, content and facilitation methods. During the programme, teachers supported classroom management and activities, and engaged with facilitators to build their capacity for independent delivery in the future.

This report presents findings from implementation research conducted during the pilot to examine programme delivery in public school settings, to estimate the programme's effectiveness in enhancing technical skills, and to assess the potential for sustainable teacher-led implementation in the future.

2. Methodology

A mixed-method approach was used to address three core research questions:

- 1. Effectiveness:** What are the effects of the STEM programme on students' and teachers' coding and robotics skills, competencies and confidence?
- 2. Sustainability:** What barriers and opportunities influence teachers' ability to continue using the skills acquired during the programme?
- 3. Perceptions:** How do participants perceive the programme, including how it responds to the needs of girls and boys?

To estimate programme impact, propensity score matching (PSM) analysis was applied to compare outcomes between participating students and a matched group of non-participants (*see section 3.3*).

2.1 Data sources

Data were collected by CodeBrave and UNICEF Lebanon as part of programme implementation (*see Table 1*). Whenever relevant, sampling and analysis incorporated differences between girls and boys, school shift and geographic differences to examine equity and inclusion dimensions. The following data sources were used:

- 1. Quantitative pre-tests and post-tests (students and teachers):** These were administered in weeks 1 and 16 of implementation to measure knowledge, skills and confidence, as well as engagement and enthusiasm. Student tests were scored out of 10; teacher tests out of 16. Differences between girls and boys were analysed to explore potential differences in learning gains.
- 2. Midline questionnaires (students and teachers):** These were collected midway through the programme implementation to assess perceptions, emerging challenges and immediate feedback – disaggregated by sex to identify potential variations in experience or confidence.
- 3. Endline principals' survey:** A survey captured school leaders' perceptions of implementation, buy-in and operational challenges.
- 4. Focus group discussions with students:** These explored students' learning experiences, enjoyment and challenges, as well as the perceptions of the programme's commitment to equal participation for girls and boys and responsiveness to the different needs of girls and boys. Sampling was intentionally balanced across girls and boys, school shifts and geographic areas, to ensure diverse representation.
- 5. Interviews with teachers:** Interviews gathered insights on facilitation, classroom dynamics and teacher readiness for independent delivery. Sampling considered whether the teachers were male or female, recognizing the influence that female and male teachers can have on girls' engagement with and confidence in STEM subjects.



6. Classroom observation checklist: Checklists were completed by UNICEF Lebanon’s team to assess delivery quality, resource availability, student engagement and logistical issues.

7. Attendance sheets for participating students: Sheets were completed by CodeBrave facilitators to track student participation.

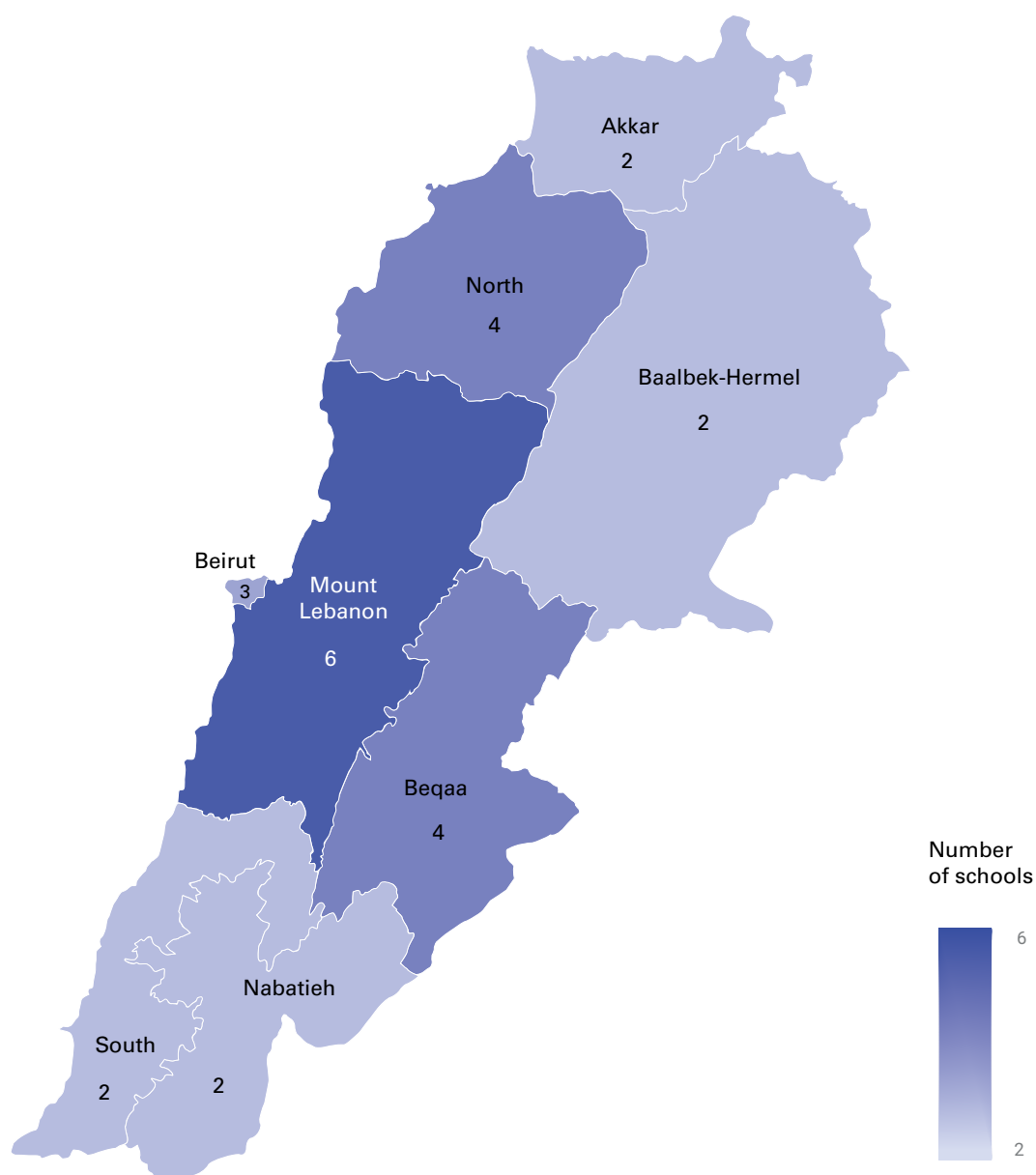
Table 1: The total number of observations by tool

DATA COLLECTION TOOL	TOTAL NUMBER OF OBSERVATIONS
Data collected from students	
Pre-test	2,761
Midline questionnaire	2,577
Post-test (participants)	2,616
Post-test (non-participants)	800
Focus group discussions	6 (3 with AM shift, 3 with PM shift)
Data collected from teachers	
Pre-test	78
Midline questionnaire	65
Post-test	62
Interviews	8
Administrative data	
Directors’ survey	25
Classroom observation checklist	11
Attendance sheets	Data for 3,012 students across 16 weeks

2.2 Sample overview

The Ministry of Education and Higher Education, with UNICEF support, selected 25 schools across eight governorates (see *Figure 1*), reaching a total of 3,012 students (approximately 120 per school). In total, 15 schools operated on a double-shift system – a morning (AM) and afternoon (PM) shift – which means the school day is divided in half and different groups of students attend each shift. AM shifts typically enrolled Lebanese students, while PM shifts primarily enrolled Syrian students. The 10 other schools ran for one shift for a full school day. *Figure 1* shows the distribution of the selected schools across governorates in Lebanon.

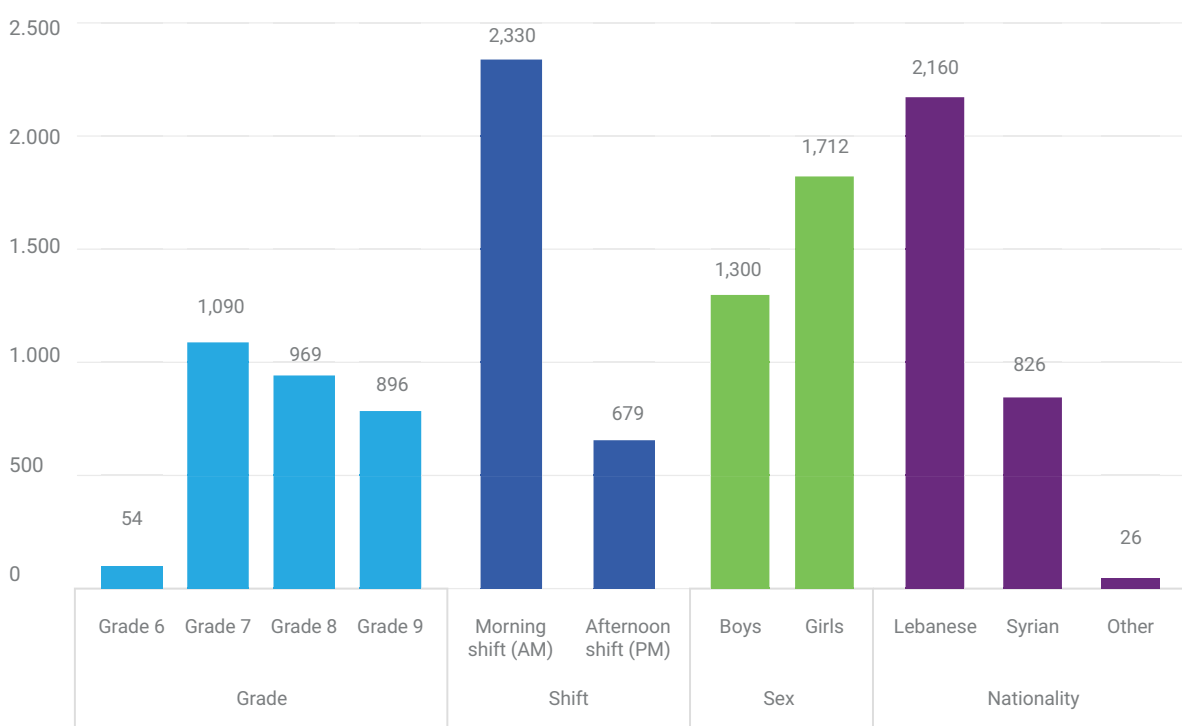
Figure 1: Distribution of selected schools by governorates in Lebanon



Note: This map does not reflect a position by UNICEF on the legal status of any country or territory or the delimitation.

Girls presented 57 per cent of overall programme participants (*see Figure 2*). There were more students from the AM shift compared with the PM shift due to a greater number of children in AM schools overall. PM-shift schools had a smaller number of students overall in the target population (Grades 7 to 9), so the intervention was expanded to target sixth graders in PM schools. Attendance averaged 86 per cent during the 16 weeks, with a 4 per cent dropout rate. Focus group participants indicated that absences were mainly due to illness or personal matters; some linked attendance challenges to transportation difficulties during strikes.

Figure 2: The number of students participating in the STEM programme by sex, grade, nationality and shift



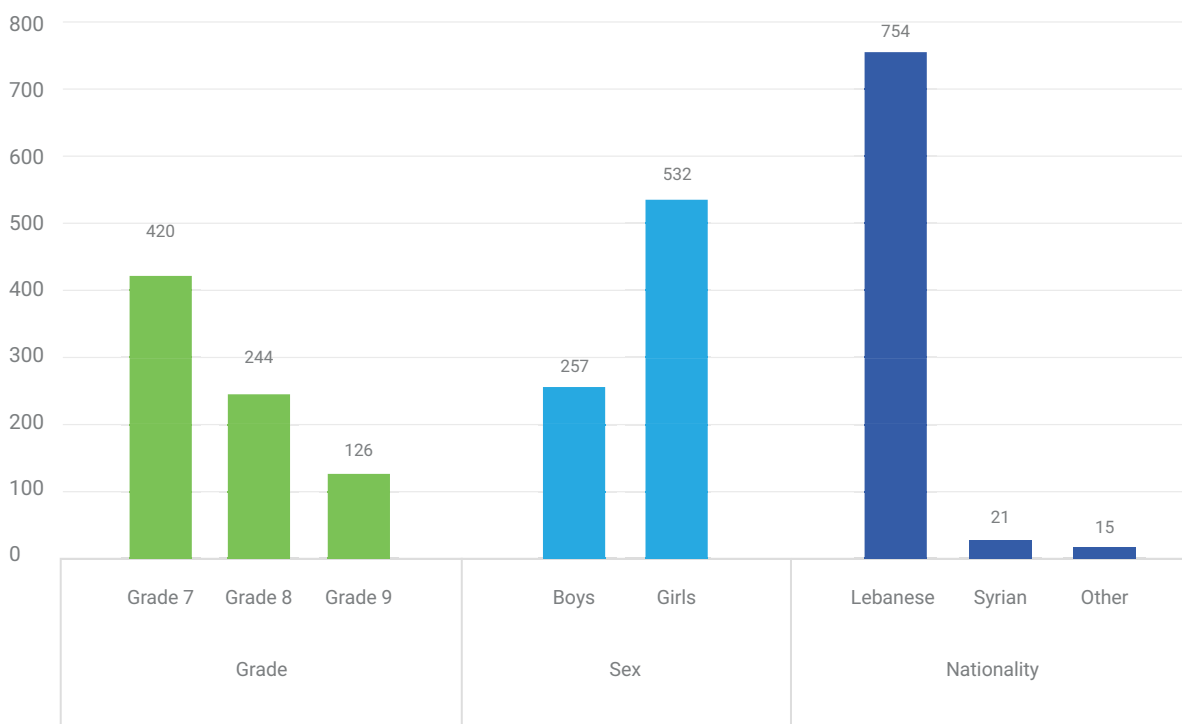
Source: Authors' analysis of attendance sheet data.

Note: Some totals do not add up to 3,012 due to missing data.

To measure impact, the comparison group comprised 800 students from non-selected classes in AM shifts. When a grade was selected, all sections were included to ensure comprehensive participation. Girls were slightly over-represented in the post-test sample, and most students were in Grade 7 (*see Figure 3*).



Figure 3: The number of students who formed the comparison group for the STEM programme by sex, grade and nationality



Source: Authors' analysis of post-test data.

Note: Some totals do not add up to 800 due to missing data.

Across the 25 schools, 78 teachers participated (62 per cent women), with an average of 12 years of experience. Among school principals, 64 per cent were men.

2.3 Limitations

2.3.1 Test design

The same 10-question assessment was used in the pre-test and post-test to minimize instructional disruption. It was short and targeted, but future studies could include more varied questions to broaden insights, reduce the risks of teaching to the test and capture complementary skills such as critical thinking.

2.3.2 Comparison group constraints

Only post-test data were available for the 800 non-participating students, and the comparison group was not randomly selected. Propensity score matching reduced bias from observable differences but cannot account for unmeasured factors, limiting the ability to fully isolate programme impact.

2.3.3 Qualitative data collection

Focus group discussions and interviews were facilitated by CodeBrave moderators, which may have introduced social desirability bias and encouraged more favourable responses. Despite this limitation, data analysis showed participants still provided candid responses on aspects of the programme that could have been improved.

3. Key findings

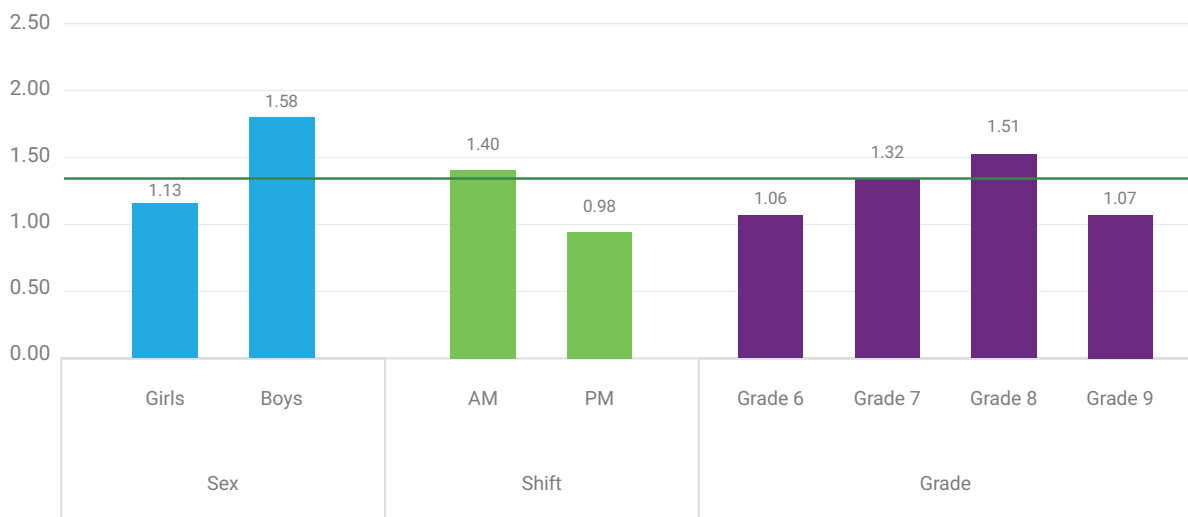
This section presents findings structured around five areas:

1. students' baseline knowledge and attitudes towards coding;
2. learning and attitude changes after the programme;
3. factors associated with learning gains, including dynamics between girls and boys;
4. programme effectiveness, measured through PSM; and
5. perceptions of the programme.

3.1 Baseline knowledge and attitudes towards coding

Students began the programme with limited coding knowledge. Average pre-test scores were 1.32 out of 10 (*see Figure 4*), and over 90 per cent of students did not pass, including 40 per cent who scored zero. Boys scored slightly higher than girls (1.58 vs 1.13), and AM-shift students scored marginally higher than PM-shift students (1.40 vs 0.98). Grade 8 students performed slightly better than other grades (at 1.51).

Figure 4: Average pre-test scores, by sex, shift and grade with the green horizontal line representing the overall average



Source: Authors' analysis of pre-test data.

While most students had some exposure to digital tools, boys and AM-shift students reported higher use across devices (see Figure 5). The internet (at 95 per cent) and smartphones (94 per cent) were the most commonly used; computers (69 per cent) and tablets (70 per cent) were used less frequently, based on students' reports. These differences highlight existing differences between girls and boys that the programme sought to address.

Figure 5: The distribution of students on the tech-familiarity index at pre-test



Source: Authors' analysis of pre-test data.

Students' perceived coding abilities were low overall, but boys consistently rated themselves more highly than girls despite similar interest levels in coding (see Table 2). AM-shift students were more likely to report being good at coding (11.91 per cent vs 8.96 per cent of the PM shift), yet PM-shift students reported higher enjoyment of coding (60.83 per cent vs 65.42 per cent of AM shift). All differences were statistically significant. These findings underscore the importance of inclusive and equity-focused STEM programmes that address the needs of girls and boys.

Table 2: The percentage of students who reported that they were good at coding and that they liked coding, by sex and shift at pre-test

		GIRLS	BOYS	AM	PM	TOTAL
I am good at coding	Yes	9.30%	14.07%	11.91%	8.96%	11.34%
	Unsure	39.14%	41.20%	41.03%	35.82%	40.02%
	No	51.56%	44.72%	47.05%	55.22%	48.64%
I like coding	Yes	61.71%	61.75%	60.83%	65.42%	61.72%
	Unsure	27.64%	27.13%	28.28%	23.88%	27.42%
	No	10.65%	11.12%	10.89%	10.70%	10.85%

Source: Authors' analysis of pre-test data.

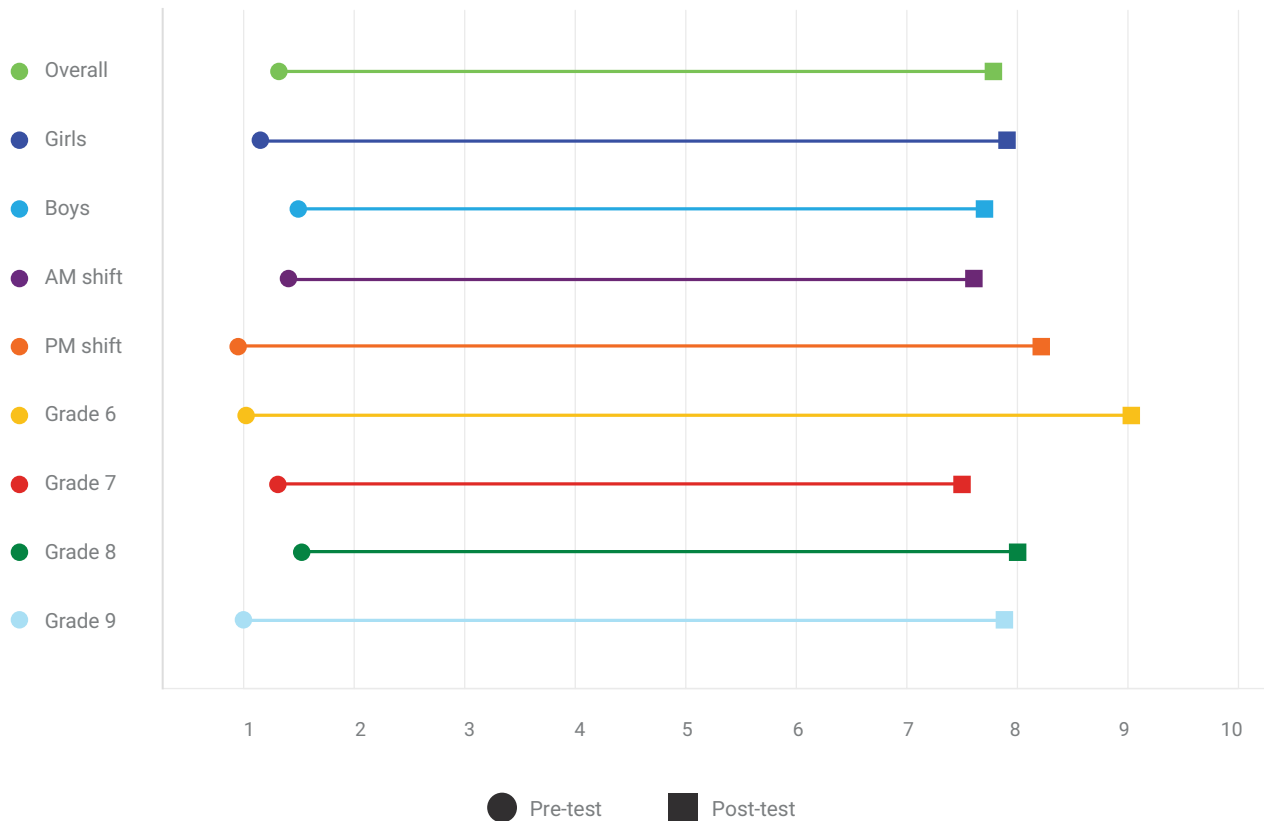
3.2 Learning and attitude changes after the programme

The programme showed strong overall learning gains. Students improved by an average of 6.5 points on a 10-point scale between pre-test and post-test (or 65 percentage points), indicating a substantial skill improvement (see Figure 6). Variation around this mean (standard deviation = 2.6) suggests most students benefited, with some achieving particularly large gains.

Gaps between girls and boys narrowed – and in some cases trends reversed.

- Girls and boys achieved similar post-test scores (7.9 vs 7.7). Girls, who began with lower confidence and lower scores, caught up by the end of the programme, closing the initial gap observed in the baseline pre-test.
- PM-shift students slightly outperformed their peers in the AM shift (8.3 compared with 7.7), despite beginning with lower pre-test scores.
- Grade 6 students had the highest average post-test score (9.0), although this was not statistically significant, likely due to the small sample size.

Figure 6: The average pre-test and post-test scores for students who participated in the STEM programme, overall, by sex, shift and grade



Source: Authors' analysis of participating students' matched pre-test and post-test data.

There were also marked improvements in attitude and confidence (see Table 3). Students reported major increases in self-efficacy and enjoyment of coding:

- Over two-thirds felt confident in their coding skills at post-test.
- Enjoyment increased sharply, particularly among PM-shift students (93.78 per cent vs 86.64 per cent of AM shift).
- Girls, who started with lower self-efficacy, matched boys in confidence at endline, highlighting the programme's potential in confidence gaps between boys and girls in STEM.

Table 3: The percentage of students who reported that they were good at coding and that they liked coding at post-test, by sex and shift

		GIRLS	BOYS	AM	PM	TOTAL
I am good at coding	Yes	66.95%	66.52%	66.49%	67.91%	66.76%
	Unsure	30.68%	29.17%	30.14%	29.60%	30.04%
	No	2.37%	4.31%	3.37%	2.49%	3.20%
I like coding	Yes	87.91%	88.20%	86.64%	93.78%	88.03%
	Unsure	9.47%	8.74%	9.99%	5.72%	9.16%
	No	2.62%	3.06%	3.37%	0.50%	2.81%

Source: Authors' analysis of participating students matched pre-test and post-test data.

Overall, the programme had a positive and equitable impact, particularly for girls and PM-shift students who faced greater barriers at baseline.

3.3 Factors associated with learning gains

A regression model using fixed-effects was conducted to understand the relationship between student characteristics and learning gains (*see Annex 2*). The model controlled for sex, shift time, grade, baseline confidence, access to devices, principal perceptions and school-level effects.

After controlling for the above factors, the regression showed that:

- 1. Girls made larger gains than boys:** Despite lower baseline skills, girls' learning gains were higher, indicating strong responsiveness when given equitable STEM opportunities.
- 2. PM-shift students outperformed AM-shift students:** Potential reasons for the better performance include smaller class sizes, more available support or different learning environments.
- 3. Students with lower baseline confidence improved the most:** This suggests that the programme effectively supported students who initially felt excluded from STEM.
- 4. Buy-in from school principals mattered:** Positive school leadership attitudes were strongly associated with better outcomes, underscoring the role leadership plays in supporting learning gains.
- 5. Access to devices influenced learning:** Although all schools received equipment, variation in class size and the resulting need for device-sharing affected outcomes.

- 6. Session disruptions affected learning progress:** Strikes and schedule interruptions negatively affected student learning, reinforcing the need for constant and sustained learning.
- 7. Grade-level and other reported challenges had limited effects on learning outcomes:** These factors showed minimal association with learning outcomes once other variables were accounted for.

These results highlight that differences between girls and boys, AM or PM shift, leadership and resource access all play an important role in shaping learners' outcomes.

3.4 Programme effectiveness: Propensity Score Matching (PSM) analysis

To estimate the impact of the STEM programme on student learning outcomes, a PSM approach was used. A PSM approach was used because students' participation in the programme was not random, and students who enrolled may have differed in a systematic way from non-participants. The PSM approach constructed a comparison group of non-participants who had similar observable characteristics to reduce selection bias.

3.4.1 Matching process

Students were matched based on three sets of baseline covariates:

- **demographics** – sex, age, nationality;
- **attitudes and interests** – self-assessed coding ability and interest in coding; and
- **digital learning engagement** – frequency of computer and mobile phone use for studying.

Covariate balance checks – both statistical and graphical – confirmed that treatment and comparison groups were well matched across all covariates (*see Annex 3*). This ensures that the observed differences in outcomes are more likely to be attributable to programme participation than pre-existing differences.

3.4.2 Programme impact

The PSM analysis showed that students in the STEM programme experienced significant improvements in test scores compared with matched non-participants (*see Table 4*). In contrast, non-participants' post-test scores did not differ from the pre-test scores of participating students, indicating that there was limited learning progress in the absence of the programme. These findings highlight that:

1. Learning gains are associated with programme participation, not external factors or existing school instruction.
2. The skills taught in the STEM programme are not typically provided in regular school curricula, emphasizing the programme's contribution to education.

Table 4: The average pre-test and post-test scores for participants and non-participants, overall and by sex, grade and shift

		PRE-TEST	POST-TEST	POST-TEST
		PARTICIPANTS	NON-PARTICIPANTS	PARTICIPANTS
Sex	Overall	1.32	1.36	7.82
	Girls	1.13	1.30	7.90
	Boys	1.58	1.34	7.71
Shift	AM shift	1.40	1.31	7.71
	PM shift	0.98	n/a	8.28
Grade	Grade 6	1.06	n/a	9.03
	Grade 7	1.32	1.25	7.49
	Grade 8	1.51	1.05	8.02
	Grade 9	1.07	2.00	7.94

Source: Authors' analysis of pre-test and post-test data for participating and non-participating students.

3.5 Perceptions of the STEM programme

This section synthesizes findings from focus groups, interviews and perception surveys, to explore how students, teachers and principals experienced the programme, with attention to differences between girls and boys, equity and classroom context.

3.5.1 Overall feedback

There was an overall positive reception to the programme. Students, teachers and principals consistently reported strong satisfaction with the programme. Initial expectations were modest (anticipating a theoretical coding course), but participants were pleasantly surprised with the programme's hands-on, interactive and real-world focus. Students described sessions as fun and engaging, noting that time flew during activities. Many wanted to explore advanced topics, such as AI, robotics, app development and game design.

"I'm curious about how Tesla cars work, how flying systems and positioning devices operate – all of these are connected to coding."

Boy, PM shift

Analysis of dynamics between girls and boys highlighted similar levels of enjoyment and engagement between both groups, with some nuanced differences. Girls tended to be more focused, attentive to aesthetics, and collaborative, while boys often preferred coding/gaming challenges and experimentation. These differences may partly reflect prior exposure to technology, as boys generally reported having more access.

“The boys were generally better at using laptops, while the girls were stronger in English. This might be because at this age, girls are often not allowed to carry phones, whereas boys usually can.”

Teacher interview

Girls reported greater adjustment in career aspirations, moving from non-STEM paths to coding or technology-related goals, while boys’ aspirations were largely reinforced rather than changed.

“My dream was to study law, but now I’ve changed my mind. I want to study programming.”

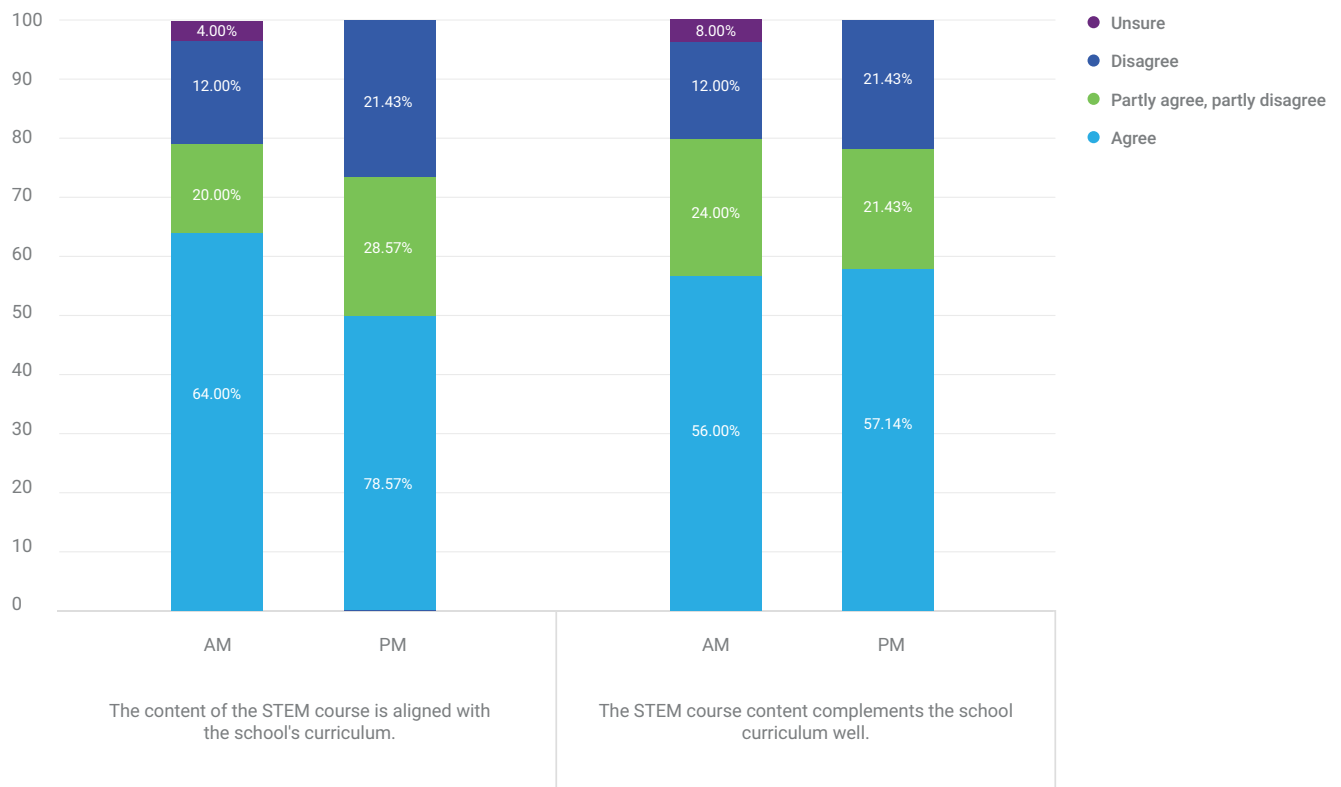
Girl, PM shift

Participants found strong links with curricular subjects, namely biology, physics and English, providing a practical applied lens to these topics. Hands-on projects, particularly micro:bit and AgriTech kits, were cited as highly engaging, practical and motivating. These projects also encouraged critical thinking about real-world issues, such as agriculture and sustainability. Principals largely agreed that the course content was aligned with or complemented the school’s curriculum and supported students’ future employability (see Figures 7 and 8).

“In AgriTech, the students were very engaged because agriculture is already part of their lives. Many of them work in agriculture from a young age – some during the potato season, others during tobacco season – and they’re used to carrying responsibility early on.”

Teacher interview

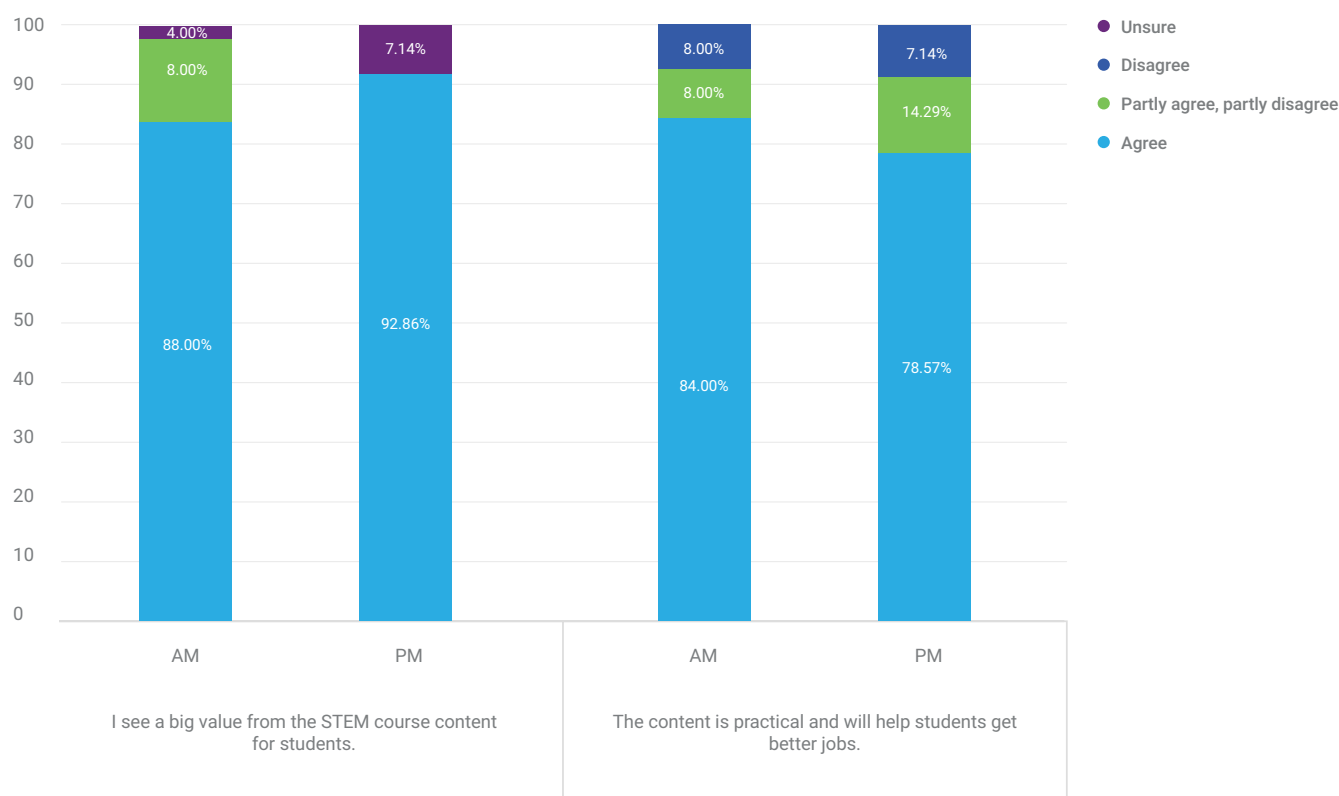
Figure 7: Principal agreement with statements around the STEM course's content alignment and complementarity with the school curriculum



Source: Authors' analysis of principals' survey data.



Figure 8: Principal agreement with statements around the course value and perceived effects on students' futures



Source: Authors' analysis of principals' survey data.

Some inconsistencies in perceptions towards session timing and pacing were observed.

The midline questionnaires suggested that most students found session timing and pace adequate, whereas the end-of-programme focus group discussions reported challenges with session length and pacing, especially for girls. This discrepancy is likely to reflect differences in the timing of data collection, with surveys at the midpoint capturing earlier perceptions when content was easier, and end-of-programme focus group discussions reflecting cumulative challenges.

3.5.2 Classroom environment and pedagogical approaches

Students highly valued facilitators' support. Focus group discussions highlighted that students appreciated how patient, approachable and encouraging CodeBrave facilitators were. They reported that facilitators created a safe, relaxed environment where students felt comfortable asking questions and making mistakes.

"Even with the teacher, it didn't feel like a typical teacher-student relationship. We felt more like brothers, companions, and friends working together."

Boy, AM shift

Collaborative learning approaches were frequently highlighted as positive aspects of the programme. Group work and peer collaboration were mentioned as effective strategies, promoting peer-to-peer learning and cooperative problem-solving. However, in some cases large class sizes made it difficult to manage group work, maintain student engagement and create an interactive learning environment.

Girls highlighted the importance of equal dynamics in student pairings and clarity in division of roles, while boys mentioned learning styles and efficiency. Additionally, hands-on, progressively complex topics maintained the engagement, and allowed students with minimal prior experience to build skills and gain confidence.

“At first, I was working alone and thought I could finish by myself, but when we did teamwork, it helped us a lot. A smart person with another smart person can do more and achieve more, so we became much faster and able to do many things.”

Girl, PM shift

Students found the practical aspects of the course very engaging. Activities that linked coding to real-world applications, such as AgriTech or micro:bit projects, were the most motivating, transforming abstract concepts into tangible, interactive experiences.

“The students really enjoy hands-on activities. For example, when you give them the micro:bit and they use it to create something like a flower, they get so excited.”

Teacher interview

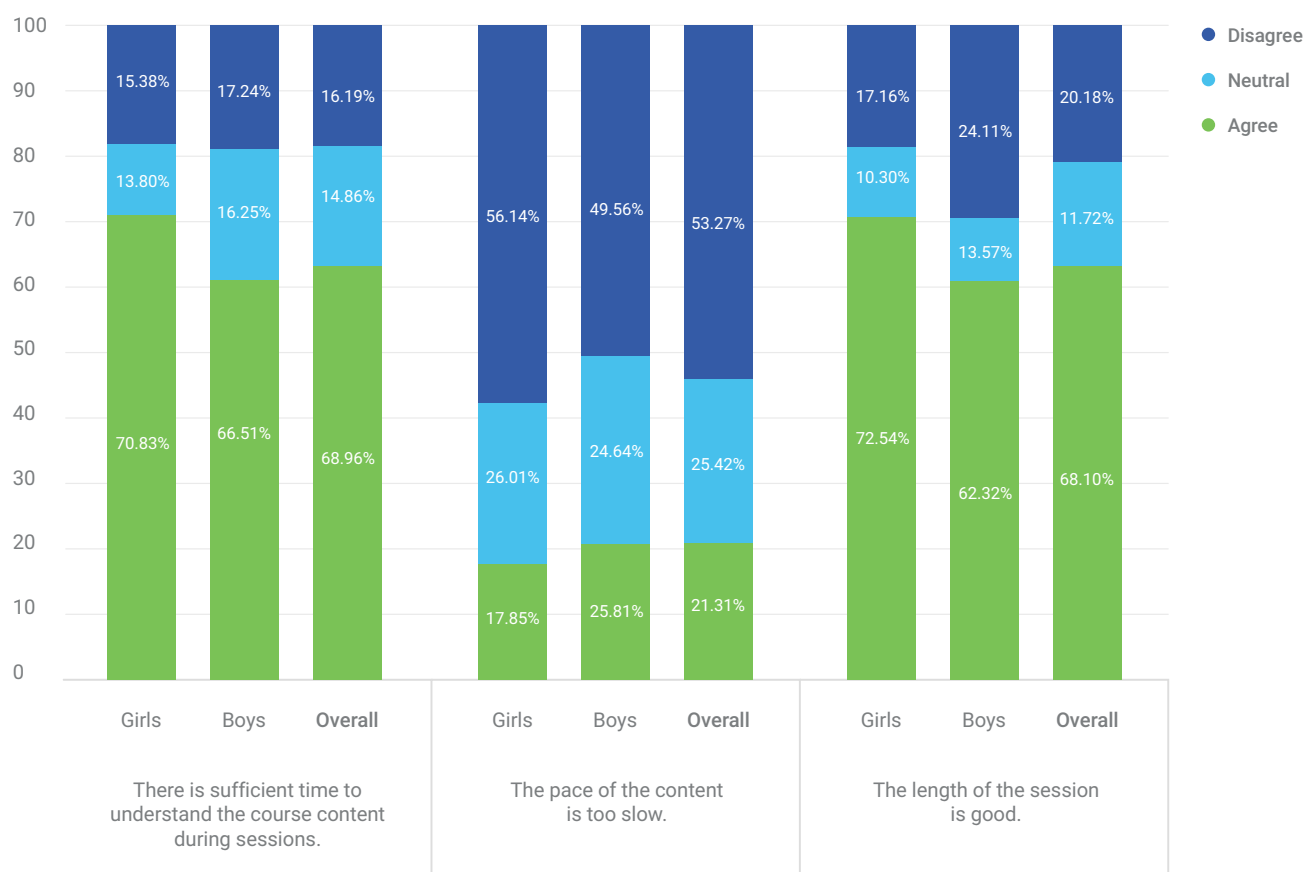
3.5.3 Challenges

Challenges relating to the pace of the course emerged. Some students, especially girls, reported that sessions were too fast or too short to fully absorb the content. These trends were evident in endline focus group discussions but not the midline questionnaires, which again may reflect differences in the overall experiences of the programme at those points in time (see Figure 9). Ramadan and scheduling disruptions due to strikes had an impact on session length, and consequently affected engagement and learning continuity. In addition, male and female teachers recognized that the integration of the course into the regular school timetable was challenging but female teachers described this as a major challenge, with clear effects on continuity, workload and teaching quality. This was often linked to the difficulty in balancing multiple roles (teaching, family, personal life) and working both morning and afternoon shifts.

“The time was very short. I felt I wanted to do more. There were things I didn’t get to finish or confirm, and I wanted to complete everything. But when we left, the time was over.”

Girl, PM shift

Figure 9: Student reported agreement around the STEM course session timing and length



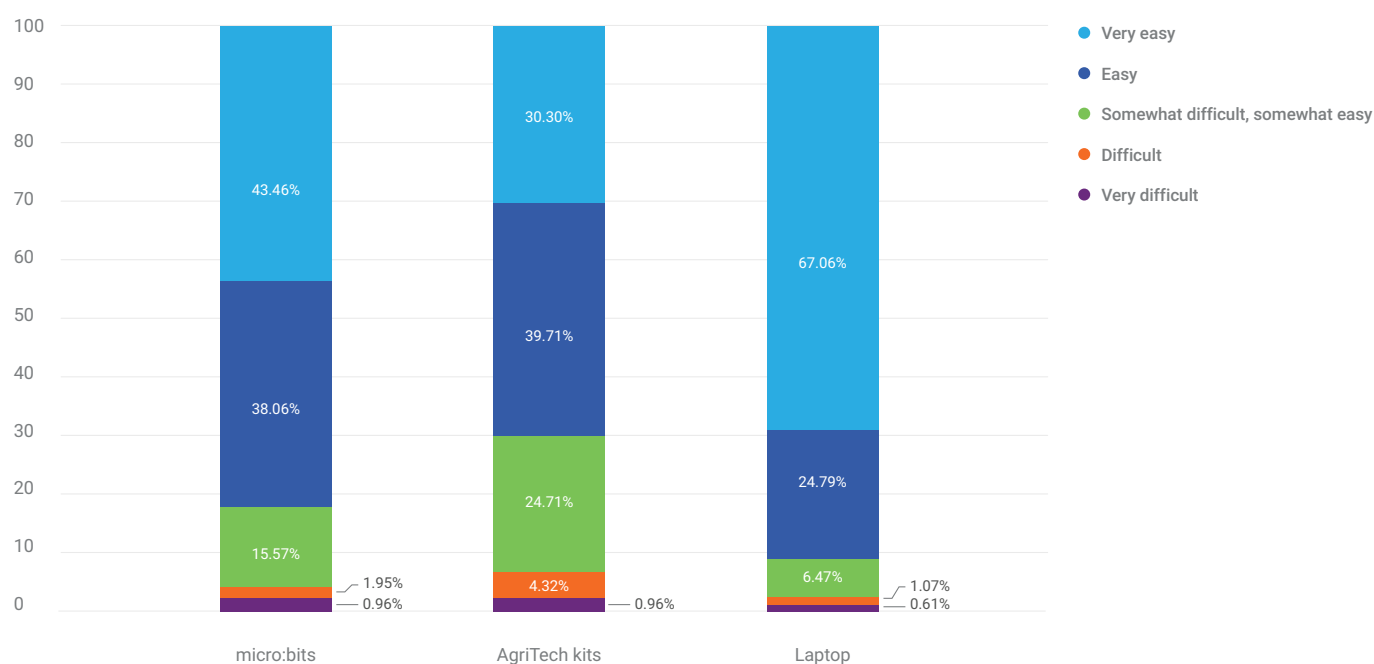
Source: Authors' analysis of student midline questionnaire data.

Access to devices and prior skills may also have posed initial challenges. Students' self-reports on the ease of using devices contrasted with teacher insights. Overall, students found the programme devices easy to use (see Figure 10), with laptops being comparatively the easiest, followed by micro:bits and the AgriTech kits. Yet, despite high self-reported rates of access to and use of devices, teachers highlighted that many students had limited prior experiences with laptops and coding. Teachers emphasized the need for students to have training on key skills, differentiated groups based on prior knowledge and sustained yearly exposure, so as to help them build confidence and progress in coding. Teachers may have been reflecting on those individual students who were more likely to struggle, which further stresses the need to map students' digital skills prior to the start of such programmes, so as to better tailor support.

"Another challenge was the students' lack of prior experience with laptops. This was particularly true for students from border areas or displaced students in our school."

Teacher interview

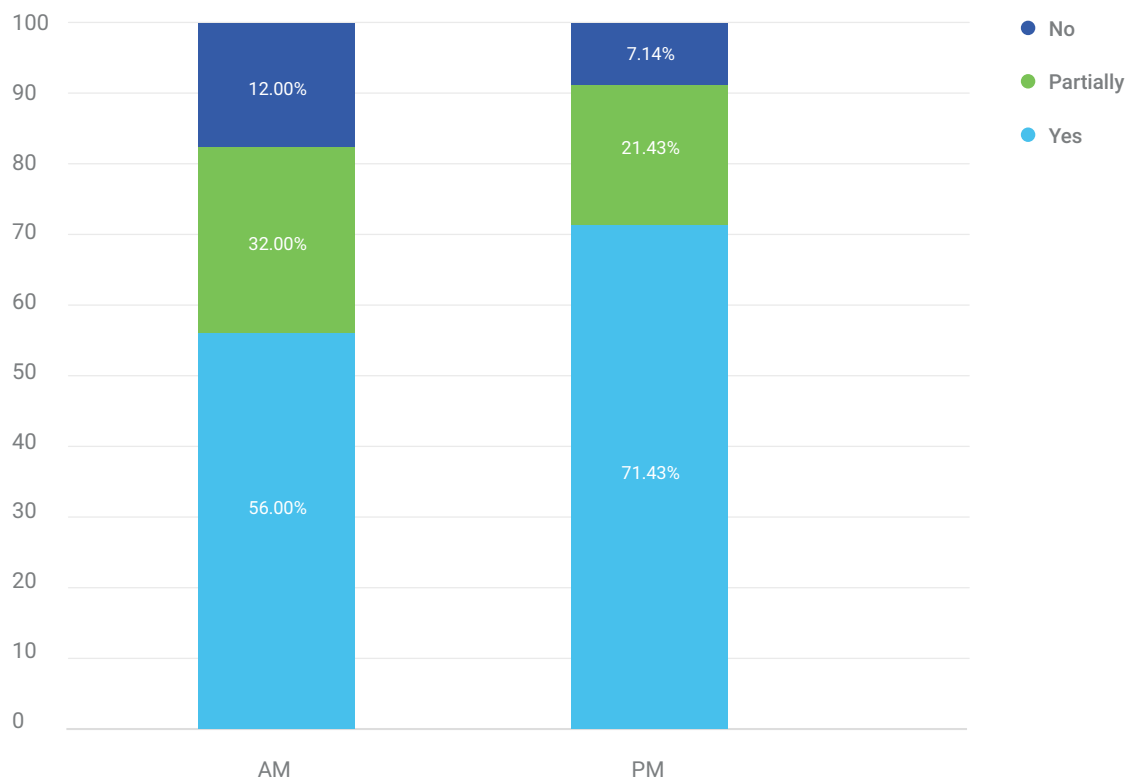
Figure 10: Student-reported difficulty around using the different programme tools



Source: Authors' analysis of students' midline questionnaire data.

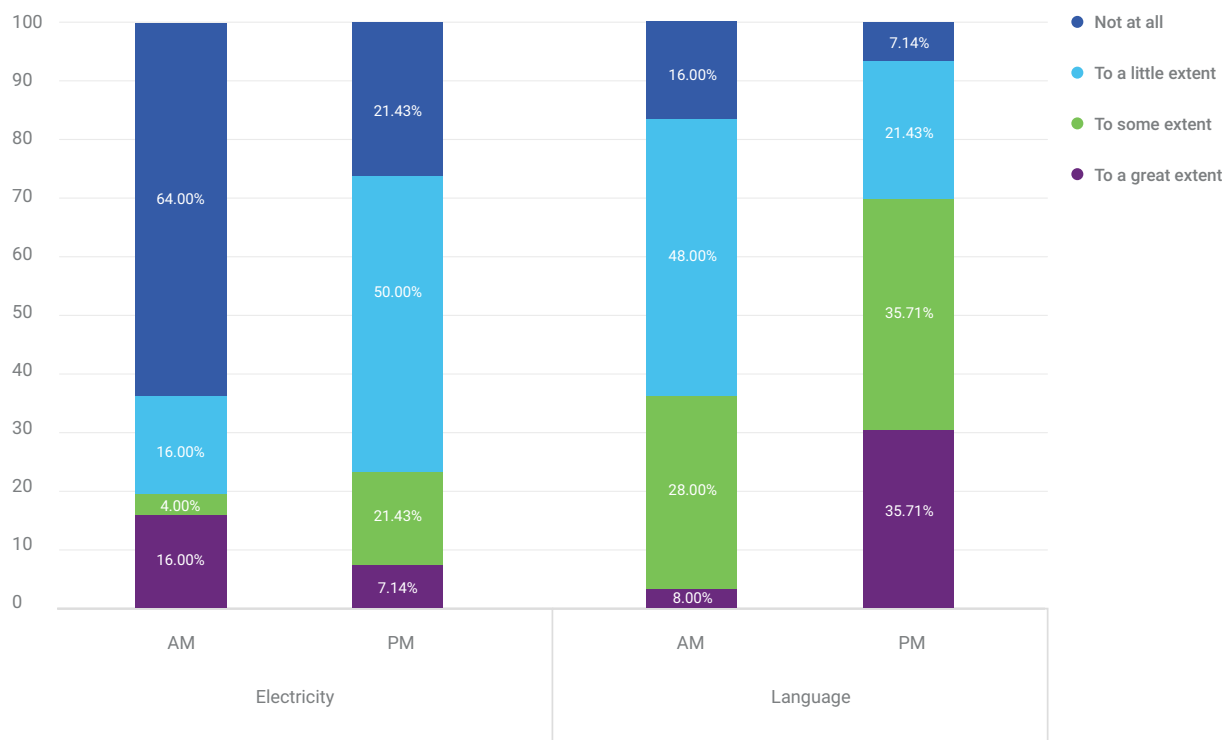
Insights from principals also revealed challenges with insufficient numbers of devices, as well as with class size, connectivity issues and language (see Figures 11 and 12). Nearly 45 per cent of principals in the AM shift and 28 per cent of principals in the PM shift reported that the number of devices was only partially sufficient or not sufficient at all. This may be linked to larger class sizes than anticipated in the AM-shift schools, compared with the PM-shift schools. A language barrier was also noted by teachers in interviews, particularly around students' knowledge of English terminology.

Figure 11: Principal reports on whether a sufficient number of devices were available in the school (micro:bits, laptops and AgriTech kits)



Source: Authors' analysis of principals' survey data.

Figure 12: Principal responses to statements regarding the extent to which the following factors posed challenges during STEM course implementation



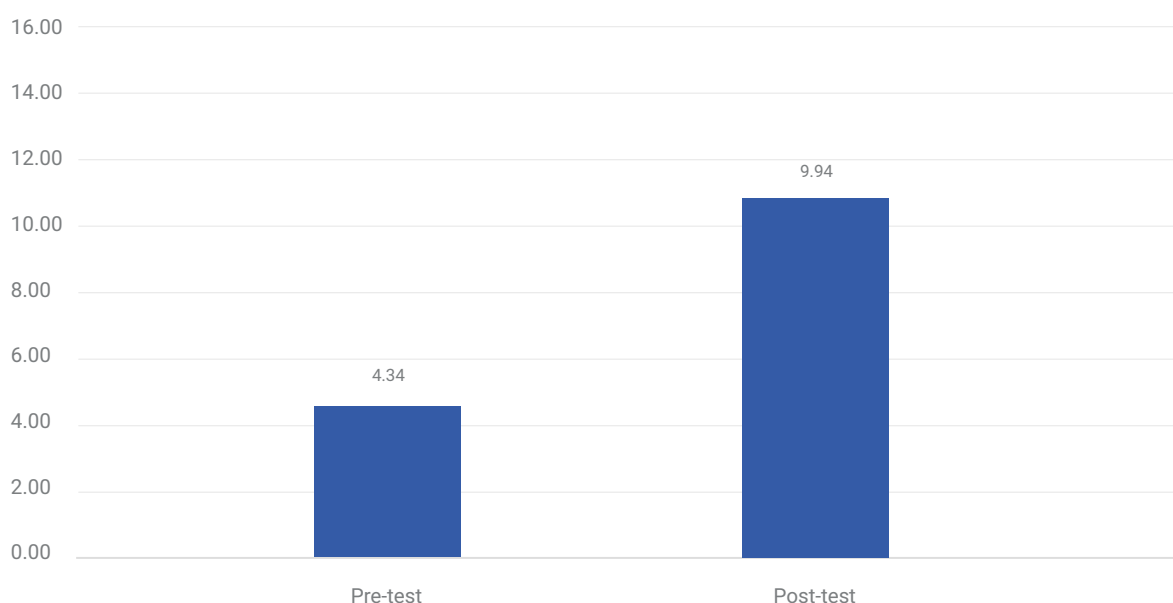
Source: Authors' analysis of principals' survey data.

3.5.4 Teacher participation in the programme

Teacher orientation sessions were well received and increases in teachers' coding and robotics skills were observed following the programme. Teachers appreciated the content, structure and facilitation of sessions, with some challenges reported for non-IT specialists, as well as with the pace of online sessions, fatigue during Ramadan and a lack of consistent follow-up after the initial orientation. Nonetheless, teachers acknowledged the benefits that orientation sessions had on their knowledge and skills.

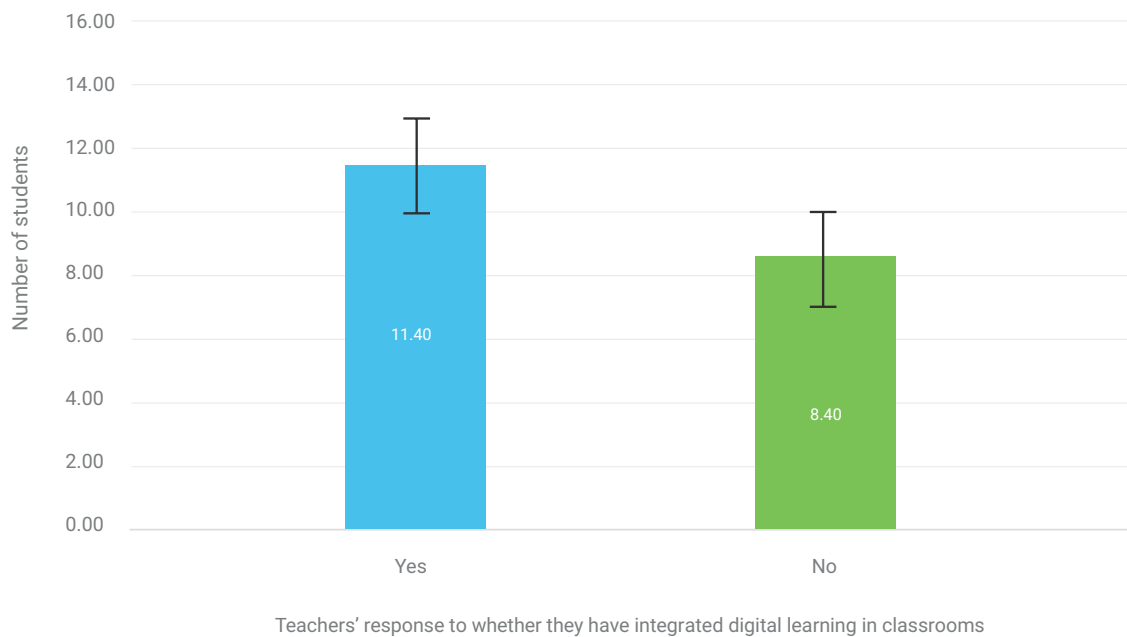
Pre-test and post-test data complement this, showing an average increase of 5.60 points scored on the test; teachers scored an average of 4.33 at pre-test compared with 9.93 at post-test (see Figure 13). Interestingly, teachers with prior digital learning experience had higher post-test performance (see Figure 14).

Figure 13: The average teacher pre-test and post-test scores



Source: Authors' analysis of merged pre-test and post-test teacher data.

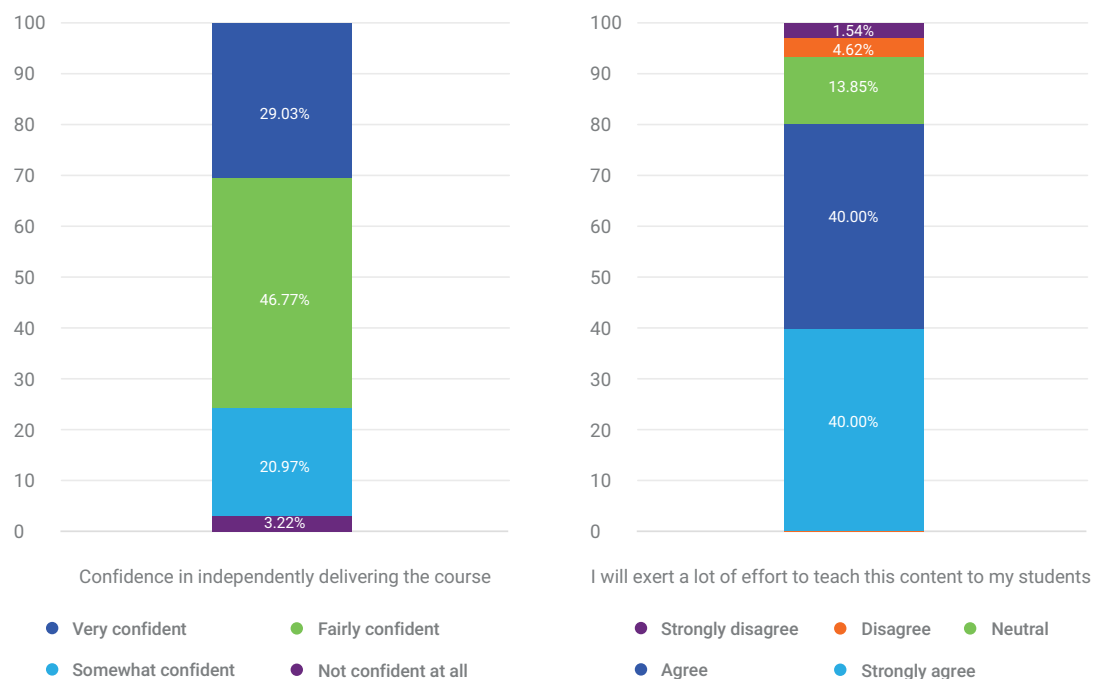
Figure 14: Teacher pre-test and post-test scores, in relation to prior integration of digital learning in classrooms



Source: Authors' analysis of merged teacher pre-test and post-test data.

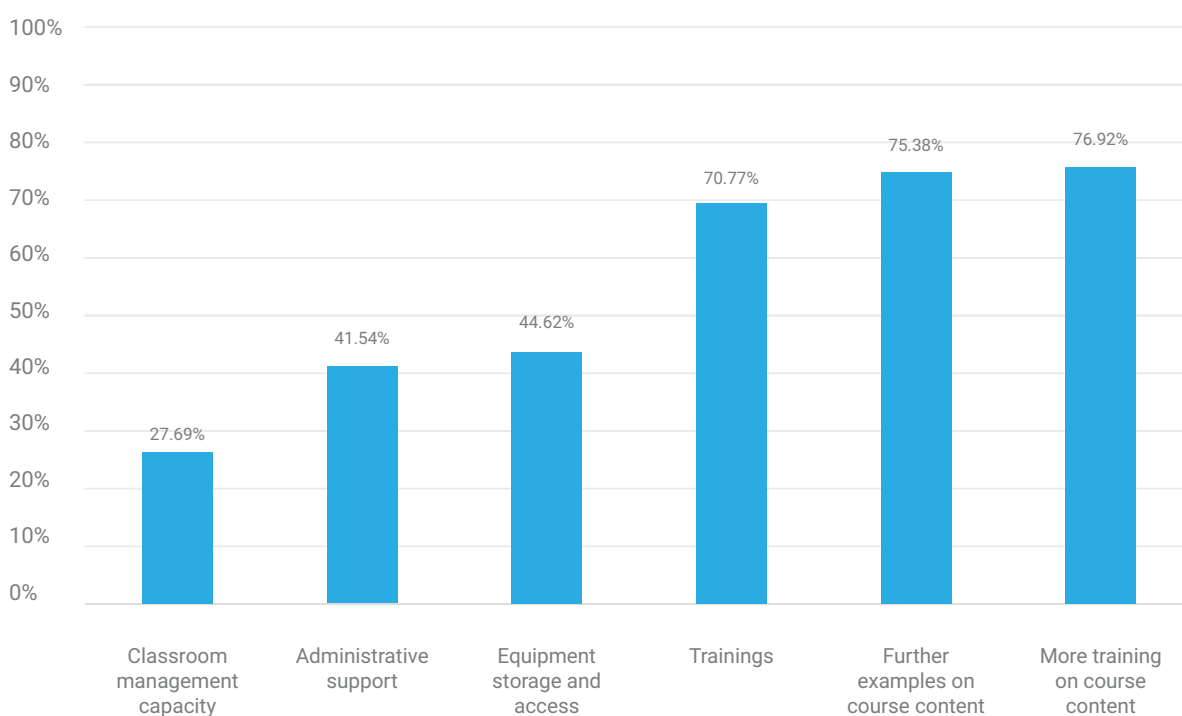
Despite increases in knowledge, teachers reported mixed readiness for independent delivery and a need for further support. While teachers reported general confidence in readiness to deliver STEM content, and agreed or strongly agreed that they would exert a lot of effort in teaching this content to students (see *Figure 15*). Teachers expressed a strong need for ongoing training, practical experience and structured guidance to enhance their ability to deliver STEM lessons (see *Figure 16*). Principals' surveys echoed these findings, with 8 in every 10 principals reporting a need for more training on course content for teachers.

Figure 15: Teacher agreement with anticipated effort to and confidence in teaching STEM independently



Source: Authors' analysis of teachers' midline questionnaire data.

Figure 16: Teacher-reported additional support needed for effective course delivery



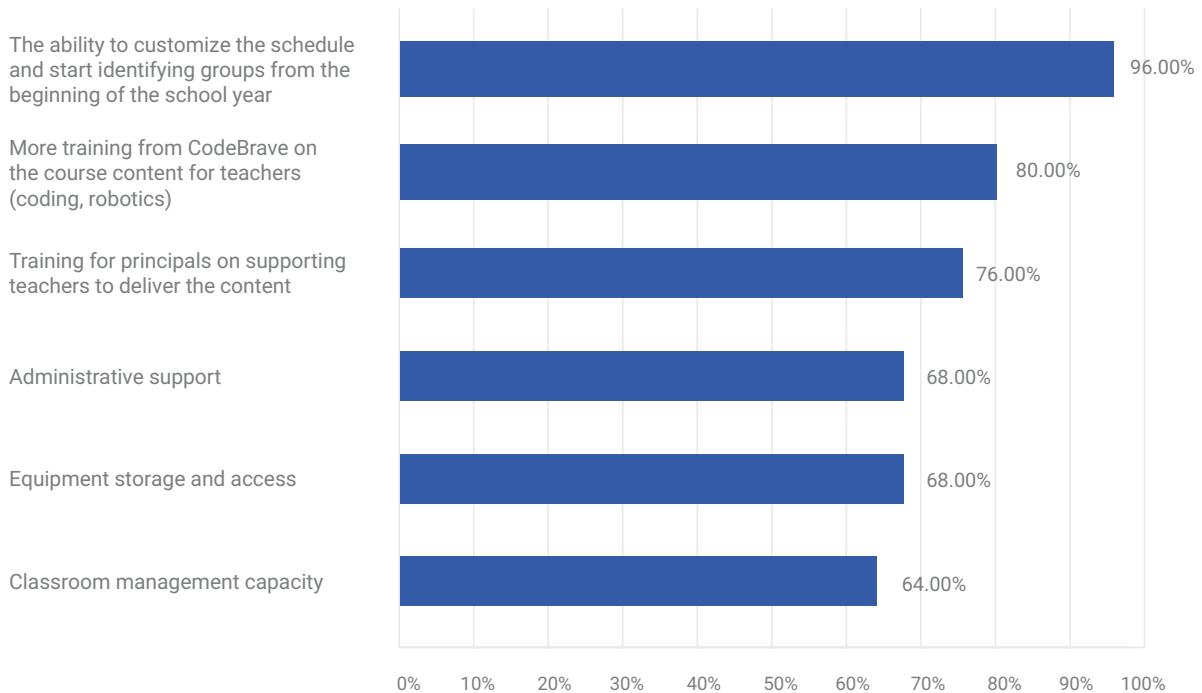
Source: Authors' analysis of teachers' midline questionnaire data.

3.5.5 Recommendations from participants

Key recommendations from participants for future programme implementation included:

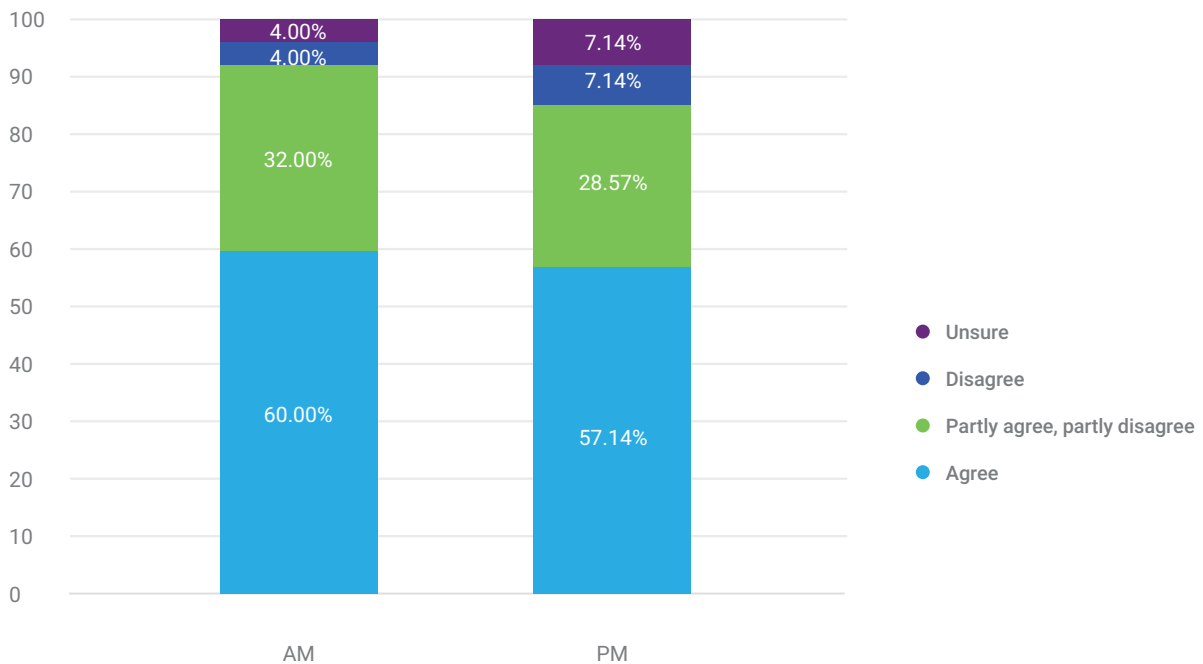
1. Increase the session frequency and duration, potentially starting earlier in the school year, which was mentioned by both teachers and principals (*see Figure 17*).
2. Ensure adequate access to devices and practical kits for all students, especially in larger classes.
3. Provide continuous, hands-on teacher training with clear guidance, ready-made projects and ongoing technical support. This investment in teachers' training is essential to ensure successful and sustainable scale-up.
4. Address language barriers and integrate STEM into the school timetable with consistent teacher roles to ensure continuity. Integration into the school timetable will require careful planning as more than a third of principals only slightly agreed/slightly disagreed or completely disagreed that there is enough time to integrate the STEM course in a regular school year schedule (*see Figure 18*).
5. Tailor group work to students' skill levels and encourage equitable collaboration.
6. Provide overall support to schools, in terms of training for principals, administrative support, logistical support and equipment storage and access (*see Figure 17*).

Figure 17: Principal-reported needs for additional support for effective course delivery in the next school year



Source: Authors' analysis of principals' survey data.

Figure 18: Principal agreement with the statement "There is enough time to integrate the STEM course content into the regular school year schedule", by shift



Source: Authors' analysis of principals' survey data.

4. Conclusion and recommendations

The STEM programme led to meaningful improvements in students' and teachers' digital and problem-solving skills, with measurable learning gains confirmed through pre-tests and post-tests, as well as the propensity score matching. The programme's hands-on, real-world design, delivered through coding projects using micro:bits and AgriTech applications, enhanced students' motivation, collaboration and confidence. The programme was particularly effective in supporting girls' engagement and shifting perceptions of STEM among girls and boys, with girls showing increased interest, confidence and aspirations to consider future STEM career pathways.

The programme demonstrates close alignment with the Lebanon Digital Learning Strategy launched in 2025, notably in the following area:

- The programme builds skills that directly contribute to the 21st-century digital competencies targeted by the strategy, through the integration of digital literacy and STEM competencies across the new curricula.
- The programme responds to the strategy's clear emphasis on strengthening teachers' digital capacity. In this regard, it is important to build on existing models with similar objectives that have already been developed and rolled out by CERD.
- The programme is aligned with the strategy's objective of promoting inclusive digital access, including the provision of devices, digital literacy, and other enabling conditions.

The pilot programme revealed challenges that must be addressed for successful scale-up, in line with the Lebanon Digital Learning Strategy, including with session timing, class size and device availability, language barriers and prerequisite skills, as well as ongoing teacher training and support. As such, the key recommendations include:

1. Integrate the STEM course into the school timetable with appropriate session length and pacing.

- Ensure clear alignment of the programme with the new curriculum and the Digital Learning Strategy, as well as the AI framework developed by the CERD.
- Agree a course schedule with the Ministry of Education and Higher Education and schools, such that it is aligned with the existing curriculum, ensuring sessions are predictable, manageable and introduced early in the school year.
- Allocate sufficient session duration and frequency to allow students to absorb new concepts, complete hands-on activities and build skills progressively, which is particularly important for girls, students with limited prior exposure and those struggling with the language of the course.

2. Support programme sustainability by strengthening teachers' digital, technical and pedagogical skills through continuous, practical support.

- Provide intensive initial training complemented by ongoing coaching and in-school support to build teacher confidence and independence in delivering the content. This is currently being planned for the school year 2025/26 under the leadership and guidance of CERD and with support from CodeBrave, as STEAM will be included as a core subject in the new curricular framework. CERD will guide the STEAM curriculum adaptation to align to the national curriculum standard as well as the design and delivery of the teachers capacity building program to integrate STEAM in teaching and learning
- Include scenario-based practice, differentiated instruction techniques and classroom management strategies – replicating effective techniques implemented in the pilot by facilitators.
- Align the STEM programme with professional development pathways, recognition and fair compensation, to sustain teacher motivation.

3. Ensure school-level readiness and classroom resources before implementation.

- Engage principals early to ensure buy-in, support flexibility and administrative needs, and provide training to enable supervision and support to teachers.
- Provide ready-made lesson plans, structured guidance and technical support for teachers.
- Manage class size and ensure sufficient device-to-student ratios, alongside support for equipment storage, access and classroom management.

4. Strengthen foundational skills and expand real-world relevance of the programme.

- Offer preparatory training for students with limited exposure to technology, including basic computer literacy, coding fundamentals and essential English vocabulary.
- Continue to incorporate and expand real-world applications to enhance relevance and improve problem-solving skills and motivation.

5. Annexes

Annex 1: List of key competencies and skills targeted in the CodeBrave STEM programme

Technical competencies

1. Programming fundamentals

- Apply core programming concepts, such as sequencing, events, loops, conditionals, variables, debugging and algorithmic thinking.
- Design interactive projects and games using Scratch and Microsoft MakeCode.

2. Physical computing

- Integrate hardware and software components to create functional systems.
- Program sensors and actuators (e.g., step counters, LEDs) to collect and respond to environmental data.

3. Data and smart systems literacy

- Collect, visualize and interpret data to solve real-world challenges, particularly in agriculture.
- Design and build smart systems using multiple input/output components (Internet of Things for micro:bit, sensors, actuators and LEDs) within the AgriTech kit.

4. Control systems and automation

- Develop automated responses (e.g., irrigation or lighting) using logic testing and iterative code refinement.

5. Measurement and reliability

- Use operators, calibration, validation and error analysis to ensure data accuracy and reliable system performance.

6. AI and machine learning basics

- Label and train datasets, test models and integrate machine learning events into projects.
- Build and refine AI-powered prototypes, such as activity recognition or smart timers, while considering ethical implications.

21st-century competencies

1. Computational thinking

- Decompose real-world problems into programmable steps.
- Design, test and debug logical sequences, comparing and justifying alternative algorithmic solutions.

2. Collaboration and communication

- Work collaboratively in defined roles to plan, code and present prototypes.
- Communicate design logic clearly and provide constructive peer feedback.

3. Resilience and adaptability

- Troubleshoot hardware and coding errors with persistence.
- Adapt solutions when data, conditions or designs change, maintaining a growth mindset.

Interdisciplinary competencies

1. Science inquiry and application

- Apply scientific concepts, such as motion, light, temperature and humidity, to technology-based investigations.
- Use sensors to measure environmental changes and explain how scientific principles inform technological solutions.

2. Mathematical reasoning and data analysis

- Use coordinates, operators and variables to control motion, compute measurements and analyse results.
- Interpret data displays (e.g., OLED readings) to make evidence-based conclusions.

3. Engineering, design and systems thinking

- Follow the engineering design cycle: define, prototype, test and improve.
- Integrate and debug hardware-software systems systematically.
- Evaluate trade-offs between efficiency, accuracy and aesthetics.

4. Physics of motion, light and sound

- Use accelerometers, ultrasonic and light sensors to explore movement, reflection and brightness.
- Model physical phenomena (e.g., gravity) through coded simulations.

Social-emotional learning competencies

1. Collaboration and relationship skills

- Work respectfully within teams, practising active listening, turn-taking and constructive feedback.
- Recognize peers' strengths and demonstrate empathy, patience and clear communication during collaborative problem-solving.

2. Critical thinking and reflection

- Analyse test results and compare multiple approaches to identify optimal solutions.
- Reflect on both technical and emotional growth through success, failure and continuous improvement.

Annex 2: Fixed-effects regression

The fixed-effects regression model was estimated to isolate and estimate the association between participation and learning gains while accounting for key background factors. To examine the relationship between student characteristics, pre-test perceptions and learning outcomes, the analysis used a fixed-effects panel regression of the following form:

$$\text{diff2}_{\{ist\}} = X_{\{ist\}}\beta + \alpha_s + \epsilon_{\{ist\}}$$

Here, $\text{diff2}_{\{ist\}}$ is the change in assessment scores between the pre-test and post-test for student i in school s at time t . The term $X_{\{ist\}}$ is a vector of student-level covariates, including sex, school shift, grade level (grade), self-reported coding ability at pre-test, principals' reports on access to devices, principal-reported challenges and principals' perceptions about the programme. The coefficient vector β captures the association between each of these characteristics and students' learning gains within schools, after controlling for all other included variables. The parameter α_s represents the school-specific fixed effect, capturing all unobserved, time-invariant characteristics of each school, such as infrastructure, leadership quality or general learning environment, that may influence student outcomes. By including α_s , the model controls for these school-level characteristics, so that the estimated coefficients on $X_{\{ist\}}$ reflect associations within schools over time. Standard errors are clustered at the school level to account for the non-independence of observations within the same school, while $\epsilon_{\{ist\}}$ is the error term.

The outcome variable in the regression was the change in test scores between the pre-test and post-test assessment for programme participants. The regression included:

- school fixed effects, which control for time-invariant differences across schools (e.g., teaching resources, school leadership, local environment); and
- a set of control variables, which include:
 - » student sex;
 - » shift timing (morning or afternoon);
 - » grade level;
 - » pre-intervention coding ability;
 - » access to digital devices at school level; and
 - » principal perceptions of the programme.

Table A1: Fixed-effects regression estimates for learning gains (diff2)

VARIABLES	(1) FIXED EFFECTS MODEL: DIFF2
male	-0.456*** (0.104)
shift	-1.126*** (0.195)
grade	0.0481 (0.0806)
good_coding_pre	-0.527*** (0.0774)
devices	0.874** (0.371)
challenges	-0.507 (1.291)
perceptions	1.364** (0.564)
Constant	2.304 (3.940)
Observations	2,033
Number of cerdid	24
R-squared	0.064
Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1	

Note: The negative coefficient for good-coding-pre likely reflects that students who initially overestimated their coding skills had less room for measured improvement over time resulting in smaller observed gains.

Annex 3: Covariate balance: standardized percentage bias before and after propensity score matching

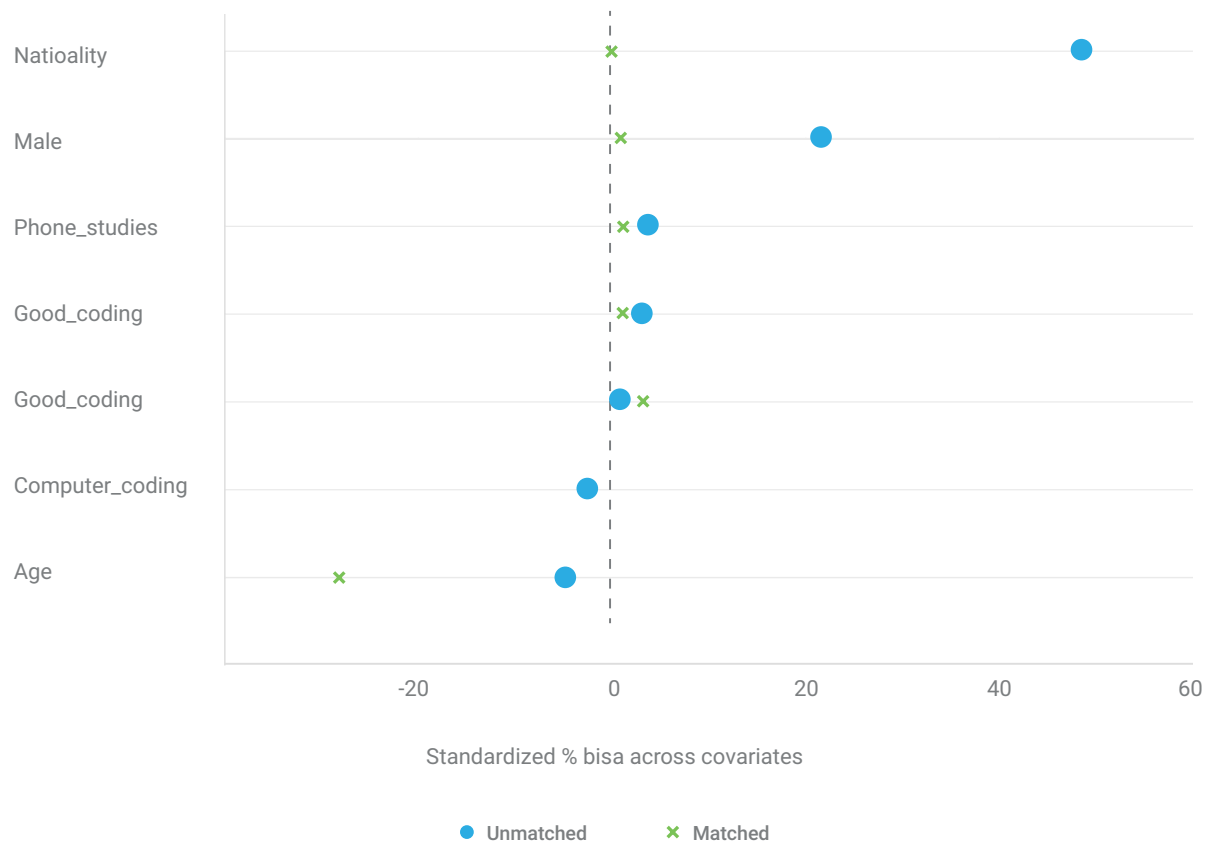
Table A2: Covariate balance: standardized percentage bias before and after propensity score matching

Variable	Unmatched	Mean		%bias	% reduct bias	t-test		V (T)/ V(C)
	Matched	Treated	Control			t	p> t	
Male	U	0.42684	0.32471	21.2		4.97	0.000	-
	M	0.42684	0.42393	0.6	97.2	0.19	0.850	-
Age	U	10.687	10.752	-5.0		-1.19	0.236	0.96
	M	10.687	11.054	-28.3	-468.5	-9.26	0.000	1.04
Nationality	U	1.2703	1.0673	47.9		10.60	0.000	1.99*
	M	1.2703	1.2703	0.0	100.0	-0.00	1.000	1.00
good_coding	U	0.62694	0.61061	2.4		0.56	0.573	0.92
	M	0.62694	0.61822	1.3	46.6	0.42	0.675	1.06
like_coding	U	1.5087	1.5278	-2.7		-0.64	0.519	0.83*
	U	1.5087	1.5281	-27	1.5	0.87	0.385	0.83*
computer_usage	U	2.0717	2.0673	0.6		0.15	0.883	0.89*
	M	2.0717	2.0499	3.0	-391.6	1.00	0.318	1.01
phone_studies	U	0.70446	0.68823	3.5		0.84	0.401	-
	M	0.70446	0.69961	1.1	70.1	0.34	0.734	-

if variance ratio outside [0.92; 1.09] for U and [0.92; 1.09] for M

Sample	Ps R2	LR chi2	P>chi2	MeanBias	MedBias	B	R	%Var
Unmatched	0.047	157.35	0.000	11.9	3.5	53.7*	1.75	60
Matched	0.015	88.48	0.000	5.3	1.3	29.4*	1.06	20

Figure A1: Standardized percentage bias across covariates before and after matching



Annex 4: Average treatment effect on the treated estimated via propensity score matching

Table A3: Average treatment effect on the treated estimated via propensity score matching

VARIABLES	(1) TOTAL_POST
psmatch2: Treatment assignment	6.502*** (0.085)
Constant	1.316*** (0.072)
Observations	2,837
R-squared	0.675
ATT	6.504360465116279
SE	.1485375171432501
Standard errors in parentheses	
*** p<0.01, ** p<0.05, * p<0.1	

Endnotes

- 1 Centre de Recherche et de Développement Pédagogiques, *PISA 2022 Report: Evidence from Lebanon*, CRDP and OECD, n.d., <https://www.crdp.org/sites/default/files/PISA%202022_0.pdf>, accessed 17 October 2025.
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