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Effects of Immersive Technologies and an Innovative Pedagogy on Elementary Education Standardized Testing, Curriculum Delivery, Student and Teacher Engagement: A Pilot Study

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ABSTRACT

Underperformance in Science, Technology, Engineering, and Mathematics (STEM) education in the United States is a persistent problem, with disparities most pronounced among women and certain minorities. Standardized testing remains the primary proficiency measure, yet traditional remedial curricula have produced limited gains. Prior research suggests that technology-enhanced, gamification-infused lessons within an innovative pedagogical framework may be more effective. This fifth-grade, observational, single-site, prospective, mixed-methods pilot feasibility study examined a teacher intervention that converted Florida's fifth-grade remedial STEM curriculum into a technology- and gamification-based pedagogy combining music videos, validated video games, drone and surgical simulation, competition-based learning, rewards, and tiered mentoring. The pedagogy, termed Stealth Learning (SL), combines multiple technology-assisted

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approaches within a single lesson plan and incorporates cross-industry learning (applications drawn from surgery) to transfer STEM-relevant skills. The study assessed whether the conversion was feasible, executable with high teacher satisfaction, and associated with improved Florida Comprehensive Assessment Test (FCAT) performance. At a Title I Florida school (98% minority enrollment), the 11 lowest-performing remedial fifth-graders enrolled non-randomly and voluntarily, completing eight two-hour after-school sessions over eight weeks; 61 peers received standard preparation. The SL pass rate was 55% (6/11) versus 26% (16/61); mean Nature of Science (NOS) scores were similar (5.63 vs. 5.59), but regression indicated SL participants reached the passing threshold at a lower NOS score (6.91 vs. 7.97). All teachers and the principal endorsed the program; attendance was 100%. Given the small, single-site, self-selected, non-randomized sample, these findings are promising but exploratory and require confirmation through larger, controlled studies.

Keywords: Curriculum Innovation and Teaching; Assessment and Evaluation; Educational Practice; Educational Technology

1. Introduction

The United States educational system faces several challenges that contribute to weak student performance. Access to quality education remains uneven in underprivileged communities, where socioeconomic constraints and educational inequality create barriers to learning. Chronic staffing shortages compound the problem, driven by declining enrollment in teacher preparation programs and difficulty filling open positions. Student mental health, particularly anxiety, also affects academic performance. Most critically, curricula in many schools remain outdated and unengaging, and do not adequately prepare students for a rapidly evolving job market or the demands of the digital age. Compounding the issue, schools have difficulty integrating new technologies into instruction. Together, these challenges underscore the need for reform to support equitable access to quality education [1].

These shortcomings are particularly apparent in Science, Technology, Engineering, and Mathematics (STEM), where U.S. performance lags international standards. National Assessment of Educational Progress data show flat overall mathematics performance among U.S. eighth graders from 2000 to 2019, with notable variation by race and ethnicity. The U.S. also has one of the lowest ratios of STEM to non-STEM bachelor's degrees globally. In China, more than 40% of college graduates earn a STEM degree, compared with about 20% in the United States—behind countries such as Mexico and France. Across 37 nations assessed for K–12 STEM education trends, the U.S. ranked 25th, indicating a need for greater investment to maintain global competitiveness and innovation [2–5].

Demographic disparities within STEM accentuate these problems. Women make up roughly half the U.S. workforce but accounted for only 27% of STEM workers as of 2019, and a gender pay gap persists in STEM fields [6]. Racial and ethnic representation is similarly uneven: Asian workers held the largest share of STEM jobs (39%), while Black workers held 18% [7]. In 2021, Black adults made up about 12% of the U.S. adult population but 9% of the STEM workforce [8]. Higher education shows a parallel gap; in 2020, Black students earned 10% of associate degrees, 9% of bachelor's degrees, 11% of master's degrees, and 7% of doctoral degrees in science and engineering [7,9]. These disparities extend to academic performance. The Program for International Student Assessment (PISA), which measures 15-year-old students in reading, mathematics, and science literacy, shows that Black and Hispanic students consistently underperform on standardized testing. On the 2022 PISA science literacy assessment, White and Asian students scored 498 and 543, respectively [10]. Black and Hispanic students scored 412 and 439, respectively, well below the average of the former two groups [10]. The gap underscores how academic performance tracks with race and ethnicity.

Standardized testing has become a central measure of educational achievement. These tests offer objective comparisons at relatively low cost, but they have notable limitations: they do not assess students holistically and can produce significant test-related anxiety. Their narrow scope often pushes curricula toward test preparation at the expense of a broader educational experience [11,12]. Analyses of the Site Acceptance Test (SAT) and the Graduate Record Examination (GRE) reveal persistent racial and gender disparities. Among top SAT scorers, Black (2%) and Latino (5%) students are markedly underrepresented compared with their White and Asian peers [13]. Women score lower than men on these tests despite comparable academic credentials [14,15], even though they earn higher grade point averages across every subject area, including math and the physical sciences—a finding that challenges the tests' predictive validity for women [16]. Time-limited multiple-choice items may disadvantage certain groups. Despite these limitations, standardized testing is likely to remain a fixture of academic assessment. Novel pedagogies and technology enhancement in STEM education have shown promise in improving both test performance and overall satisfaction among teachers and students [17]. Progress toward equity-focused practice therefore depends on the deployment of inclusive learning environments that shape how curriculum content is presented and delivered—to support engagement, mastery, and career-relevant skills.

To address these challenges, emerging technologies such as robotics, artificial intelligence (AI), metaverse technologies, the Internet of Things (IoT), educational robots and chatbots, and virtual labs may enhance STEM education [18–20]. These tools can support personalized learning, programming education, adaptive assessment, entrepreneurship, and immersive learning experiences [21–23]. Innovative curricula and emerging technology may also help address the gender and racial gaps in STEM performance. Technological approaches have been shown to reshape gender equity in STEM education by offering new ways to build inclusive learning environments. Strategies such as faculty mentorship, hands-on learning, and culturally responsive teaching have been associated with increased female participation and retention in STEM fields [24–27]. Inclusive programs can also connect students from historically marginalized communities to STEM opportunities and professionals [28–30].

AI offers substantial possibilities in STEM education, particularly when combined with other emerging technologies. AI-based learning systems can provide customized learning experiences and enhanced support systems [31], natural language processing for intelligent tutoring system feedback [32], eye tracking in programming education [33], predictive analytics for students who need additional support [34], and recurrent neural networks for identifying at-risk students [35]. The IoT can provide practical, hands-on learning experiences [36,37] and supports inquiry-based and project-oriented learning [38]. Extended reality (XR), including augmented reality (AR) and virtual reality (VR), can enhance STEM education through immersive, interactive experiences that aid retention of complex concepts [39–41]. These technologies support active participation and collaboration and can shape problem-solving and critical-thinking skills [42]. In addition, VR applications using a head-mounted display with integrated eye tracking can screen for functional vision problems (FVPs) in children—an important identification step, as these students often require instructional modifications [43].

Educational robots and chatbots can broaden learning modes [44], influence early education by developing cognitive skills and environmental awareness [45–47], and support computational thinking. Incorporating social cognitive theory into a curriculum emphasizes learning through observation and social interaction and is particularly effective when paired with robotics. Such tools facilitate collaborative, hands-on projects and provide the real-time interaction and feedback that this theory describes [48]. Behaviorism-based design—students responding to external stimuli supported by immediate feedback, adaptive quizzes, and interactive simulations—can also benefit learning [49]. Virtual labs support experiential learning by allowing students to engage with and reflect on interactive experiences [50–52]. Game-based learning in context-dependent settings further supports motivation [53] and aligns with situational learning theory. One example is mStikk, a mobile-based serious game designed to help Biomedical Laboratory Science (BLS) students master phlebotomy—a procedure in which pre-analytical errors account for approximately 62% of clinical laboratory mistakes. The app provides a simulation-based alternative to passive methods such as lectures and textbooks by allowing repeated procedural practice outside the classroom. It uses gamification elements, including visual and audio cues and a scoring system, to support mastery of tasks such as equipment selection, reading requisitions, and handling blood tubes [54]. Emerging technologies grounded in validated learning theories therefore have the potential to reshape STEM education.

This investigation tests whether a state elementary school remedial curriculum in STEM can be converted into an engaging technology- and gamification-based program using an innovative pedagogy termed Stealth Learning (SL).

It examines whether this program is associated with improved performance on a state standardized science exam and whether it can be delivered with high satisfaction among teachers and principal and with high student attendance. Most technology-based curriculum restructurings leverage a single innovative feature. This approach is distinct in that it combines several elements of technology-enhanced STEM education within one program. The full remedial cognitive lesson plan was converted into music videos with customized scripting and music; additionally, video game, surgical, and drone simulation exercises develop career-relevant technical skills alongside scientific method exploration, math and charting. All tools include a gamification component anchored by competition-based learning (CBL). SL also draws on traditional educational practices: small-group, station-based collaborative activities; frequent low-stakes multiple-choice and short-answer assessments; friendly competition with non-monetary recognition; and layered mentorship spanning teacher-to-student, peer-to-peer, and professional connections.

2. Materials and Methods

2.1. Study Design

This investigation was a fifth-grade, observational, single-site, prospective, mixed-methods pilot feasibility study comparing standardized-test performance between an after-school enrichment intervention and a non-intervention comparison group. The primary question was whether the standardized remedial curriculum for the Science Florida Comprehensive Assessment Test (FCAT) could be converted into a technology-enhanced lesson plan using an innovative pedagogy (SL), and whether that curriculum could be delivered within the same timeframe as the standard one. Quantitative outcomes—Grade 5 Science FCAT total scores and Nature of Science (NOS) subsection scores—were paired with qualitative measures of teacher and principal satisfaction. Given the historically poor attendance of the remedial program, attendance was also captured to evaluate whether it improved under the SL program. The design was exploratory rather than confirmatory; findings are accordingly framed as preliminary indications of feasibility and direction rather than as a definite demonstration of effectiveness.

2.2. School Profile and Standardized Tests

The program was conducted at a Title I (poverty-based eligibility for free or subsidized lunch) elementary school in a high-poverty area in Florida. The school had historically faced challenges with student academic performance overall and on standardized tests, reflected in its “D” grade in the previous academic year [55,56]. FCAT scores for that year showed disparities across subjects: English Language Arts (37% passing), Mathematics (49% passing), and Science (18% passing) [56].

The FCAT was Florida’s criterion-referenced statewide assessment, administered annually to students in grades 3–10 to measure proficiency in reading, writing, mathematics, and science against state-adopted academic standards [57]. The Grade 5 Science FCAT consisted of two 80-min multiple-choice sessions drawing on cumulative benchmarks from grades 3–5 and was reported on a five-level achievement scale (Level 1 lowest to Level 5 highest); the lowest scale score of Level 3 was the passing standard for on-grade-level performance [58]. The Grade 5 Science FCAT is divided into four reporting categories: NOS, Earth and Space Science, Physical Science, and Life Science. The NOS subsection accounts for one-fourth of the exam and is scored on a ten-point scale. NOS measures whether students can think and work like a scientist and assesses three skills: (1) defining a problem, planning an investigation, and analyzing and interpreting data; (2) recognizing that scientific explanations must be grounded in observable, testable evidence; and (3) understanding that results from a scientific investigation should be replicable by others [58]. The NOS subsection was identified by the school’s science coach as a critical determinant of passing the overall Science FCAT. The science coach is a teacher specialist responsible for executing all lesson plans associated with the science curriculum. Assessment data used in this analysis were drawn from the state-administered FCAT and from the school’s routine weekly remedial-monitoring records. All FCAT performance assessments were conducted by the state department of education. No additional invasive or experimental measurements were collected.

2.3. Group Selection and Comparability

The entire fifth-grade class was non-randomly divided into an intervention group (SL lesson plan) and a non-intervention group (non-SL lesson plan). The full cohort (n = 72) was evaluated for program eligibility. The intervention group (n = 11) was identified through the school's existing weekly remedial-monitoring assessments: students in the lowest-performing tier were invited to participate voluntarily, consistent with the school's established practice of routing such students to after-school remedial instruction. SL participation required after-school transportation arranged by the family and parental consent. All identified students opted in (100%). The non-intervention comparison group (n = 61) consisted of the remaining members of the same fifth-grade cohort. The SL group was, by selection, lower-performing than the non-SL group. Otherwise, the two groups were drawn from a population with substantial socioeconomic and demographic homogeneity: the fifth-grade class was uniformly classified as economically disadvantaged through eligibility for the federal free or reduced-price lunch program.

2.4. Teacher Training

The intervention team comprised four medical students who assisted with skill-station instruction, four classroom teachers, and one science coach. The science coach and the four classroom teachers completed a three-hour training session prior to program launch, in which they reviewed all cognitive teaching materials and rehearsed the activity protocols for each session. The teachers rotated from session to session. The four medical-student assistants were already proficient in the SL pedagogy from prior involvement with related programs and required no additional training; they participated in every program session. Cognitive and skill-station content was developed with the teachers and a senior SL curriculum-conversion expert, who led the pedagogical conversion of the standardized fifth-grade science curriculum into the SL format used in this study. The school principal was present during program execution but acted purely in an observational capacity and did not deliver instruction or assess student outcomes.

The program was conducted with the approval of the host school's administration. Written parental consent was obtained for all students who participated in the after-school intervention. Because the program operated as a school-administered after-school enrichment activity using routine educational assessment data, formal Institutional Review Board (IRB) review was not sought; the activity falls within the category of educational practices in established settings as defined in 45 CFR §46.104(d)(1)[59].

2.5. Curriculum Conversion

2.5.1. Standard Science FCAT and NOS Instruction

A goal of this project was to develop a technology-enhanced curriculum addressing performance deficiencies on the Science FCAT and its NOS subsection. The NOS was selected by the teachers because of its role in building foundational scientific literacy and its historically poor performance. In the standard approach, teachers develop weekly lesson plans aligned to state standards and administer weekly FCAT-style assessments. Practice items are also drawn from a state-approved *Depth of Knowledge* question bank, which uses FCAT-style prompts presented in a written-response format. Three benchmark assessments are administered across the school year. NOS content is taught during the first four weeks of the school year (1 h per day, five days per week, totalling 20 h) and is reinforced one hour per week until the May FCAT administration (an additional 32 h), for a total of approximately 52 h of NOS instruction per academic year.

2.5.2. Pedagogy Components

The overriding framework for the curriculum conversion is SL. SL is a brain-based, empirically informed educational approach designed to support engagement and knowledge and skill transfer through high-affinity pop-culture media such as music, videos, and video games. It combines visual, linguistic, and kinesthetic approaches to learning. It is described as brain-based because certain components engage neurophysiological responses thought to support knowledge acquisition and mastery. Other features include custom music videos that contain all cognitive material in the lesson plan; students did not have to read the material but experienced the videos with the teacher as a contextual guide. All laboratory exercises were converted to technology-enhanced activities that reinforced the scientific method, math and charting competency alongside career-skill building—cross-industry learning (CIL)[60]. SL also integrates traditional, validated educational practices: small-group, station-based collaborative activities; frequent low-stakes multiple-choice and short-answer assessments; friendly competition with non-monetary recognition; and layered mentorship spanning teacher-to-student, peer-to-peer, and professional connections. SL does not change what is taught; it modifies how the content is delivered, with the aim of supporting student engagement and cognitive transfer (**Table 1**).

Table 1. Components of the Stealth Learning Curriculum.

Educational Component	Specific Curriculum Implementations
Multi-Sensory Based Content	Curriculum Animoto Music Videos
Collaborative Stations	Top Gun Surgeon Laparoscopic Skills & Suturing Program
Validated Video Games	Super Monkey Ball Video Game
Simulation Tools	Real Flight Drone Simulator
Assessment Methods	Frequent Exams, Competitions, and Rewards
Education Enhancement	Spelling Bees and Quizzes
Mentorship Types	Teacher to Student, Peer to Peer, and Professional Connections

2.5.3. Session Details

The eight sessions were delivered during the spring semester preceding the May FCAT administration. Cognitive content was developed from the fifth grade *Promoting Science among English Language Learners* (P-SELL) workbook, which is aligned with the Florida Next Generation Sunshine State Standards. The unit emphasized the three NOS benchmarks tested on the Grade 5 Science FCAT, identified using the Florida Next Generation Sunshine State Standards benchmark codes (formatted as SC.[grade].[strand].[standard].[benchmark], where SC denotes Science): SC.5.N.1.1 (defining a problem, planning an investigation, and analyzing data), SC.5.N.2.1 (distinguishing observations from opinions and recognizing the importance of evidence), and SC.5.N.2.2 (the importance of replication and reasons for variation in data).

Assessment items adapted from the P-SELL workbook were rewritten to align with the converted curriculum. Each session was approximately two hours in length and was held in a classroom equipped with a video projector and sound system. The 11 students were divided into three rotation groups, and each group cycled through the session's three stations. The science coach and teachers led the cognitive (music-video) station, while medical mentors led the skill stations. Two motivation mechanisms supplemented instruction: students earned participation ribbons at each station, and a curated streaming portal hosted the music videos for at-home viewing, with a keyword presented at the end of each video that students could submit to earn additional ribbons.

(1) Session 1—Orientation and Baseline: What Do Scientists Do?

The first session opened with a brief introduction in which the science coach reviewed program objectives, introduced students to the educators and mentors, and oriented them to the rotation structure. The remainder of the time was divided into three stations: the cognitive music-video station and two skill stations. The cognitive station presented music video #1, "What Do Scientists Do?", followed by an educator-led discussion and a second viewing to anchor the SC.5.N.1.1 vocabulary. The first skill station was the video-game station (**Figure 1**), featuring the previously validated *Super Monkey Ball*, a console game in which the controller's joystick pilots a spherical ball around a dynamic, undulating course while targeting specific items [61]. The station followed a fixed protocol modelled on the scientific method, with each student rotating through the roles of (a) timer, (b) scorekeeper, (c) player, and (d) data recorder. Performance was scored as time to complete the course minus a penalty for errors, providing a concrete numeric outcome that students could record, compare, and discuss. The second skill station was the Top Gun Bean Drop (TGBD) surgical-simulation exercise. In this activity, the student uses the non-dominant hand to manipulate a laparoscopic grasper, pick up a bean-shaped object, and deposit it through a 1-cm aperture into a metal cup, with the working field visible only on a video monitor. Ten beans were transferred to complete a trial. The simulator includes gamification features: each error triggers a light and buzzer, and the device automatically records errors and elapsed time. Students worked in teams of two under medical-professional supervision: one student performed the exercise while the partner operated the camera to provide the on-screen view, with remaining group members serving as time/scorekeeper–data recorder and observer. Roles rotated so that every student cycled through (a) camera operator, (b) surgeon, (c) time/scorekeeper/data recorder, and (d) observer. Educational goals included observation, computing, recording, charting, and graphing. The Top Gun Simulator and Bean Drop equipment are shown in

Figure 2 and **Figure 3**, respectively.

Figure 1. *Super Monkey Ball* console video game used at the cognitive-skill station to model scientific-method roles (timer, scorekeeper, player, data recorder).

Figure 2. Top Gun laparoscopic surgical simulator used as a fine-motor and observation skill station for the Bean Drop exercise.

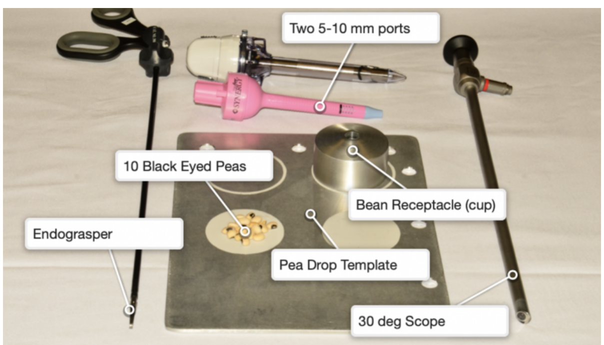

Figure 3. Bean Drop exercise materials (laparoscopic grasper, beans, and 1-cm-aperture cup) paired with the Top Gun Simulator to assess non-dominant-hand dexterity and observational data recording.

(2) Session 2—Observation Skills: Qualitative vs. Quantitative Data

The second session focused on the observational skills underlying SC.5.N.2.1 and was divided into three stations. The first station presented music video #2 (Observations) and music video #3 (Qualitative versus Quantitative Analysis), each followed by an interactive workbook activity led by the teachers. The second station used *Super Monkey Ball* so that students practiced making and recording qualitative and quantitative observations during gameplay. The third station repeated the TGBD simulation from Session One, with the framing shifted from procedure mastery to systematic observation: students recorded both qualitative descriptions of technique and quantitative data (errors and time) generated by the trainer's electronic proctor.

(3) Session 3—Inference and Prediction: Introducing Drones and the Virtual Simulator

The third session introduced drones and the drone virtual simulator across three stations. The cognitive station presented music video #4 (Inference and Predictions), followed by the assigned workbook activity. The first skill station was "Hover Buzz" (HB), an instructor-piloted demonstration in which students observed and recorded the flight characteristics of miniature drones to support inference and prediction practice. *Teeny Drones* (Teeny Drones, Montreal, Canada) were used for the physical drone exercises (**Figure 4**)[62]. The focus of this station was the development of analytical observational skills. The second skill station was the virtual *RealFlight* drone simulator (RFDS), a laptop-based radio control flight simulator with a wired transmitter interface used to emulate the controller dynamics of an actual drone (**Figure 5**)[63]. Students practiced take-offs and landings in supervised pairs, with each group member rotating through the roles of pilot, observer, timekeeper, and scorekeeper.

Figure 4. *Teeny Drones* (Teeny Drones, Montreal, Canada)[62]. Miniature drones used in Session 3 to give students hands-on practice with analytical observation of flight characteristics.

Figure 5. Laptop-based RealFlight radio control flight simulator[63] used in Session 3 for paired psychomotor practice with rotating team roles, and in Session 5 for guided formulation of testable questions and experimental design preparation.

(4) Session 4—How Scientists Understand the Natural World: Experiments and Workbook Assessment

The fourth session featured three stations. The cognitive station presented music video #5 (How Do Scientists Understand and Explain the Natural World) and music video #6 (Experiments), followed by review of the assigned workbook materials. The first skill station repeated the TGBD exercise, this time performed with the dominant hand; completion times recorded by the simulator's electronic proctor were compared to the non-dominant-hand data collected in Session One, giving students a paired-trial dataset on which to practice replication and data variation (SC.5.N.2.2). The third station consisted of working through the assigned workbook practice-assessment questions as a group.

(5) Session 5—The Inquiry Framework: Experimental Design with the Drone Simulator

The fifth session consisted of three stations. The cognitive station presented music video #7 (Inquiry Framework) and music video #8 (Performing Good Scientific Inquiry). The RFDS station was repeated, but the educator guided students through formulating a testable question and drafting an experimental design grounded in drone aviation, in preparation for the live drone experiment in Session Six. The third station was a spelling and vocabulary review delivered in a "spelling bee" format to reinforce NOS terminology.

(6) Session 6—Variables and Controls: The Drone Lift Experiment

The sixth session consisted of three stations. The cognitive station presented music video #9 (Variables) and music video #10 (Control Group), reinforcing the experimental-design vocabulary introduced in Session Five. The second station reviewed the remaining practice-assessment questions and worked through the answers as a group. The third station was the Drone Lift Experiment: under the guidance of teachers and instructors, students executed the inquiry-framework experiment they had designed in Session Five, using the miniature drones to evaluate flight-time degradation as a function of payload weight. The activity required students to identify independent and control variables, collect timing data across trials, and discuss sources of variation, providing a concrete application of SC.5.N.1.1 and SC.5.N.2.2.

(7) Session 7—Cumulative Review: Music-Video Quiz and Spelling-Bee Finale

The seventh session was divided into two segments. The first was a cumulative quiz drawn from the music-video content; correct answers were reviewed item by item, and items keyed to end-of-video keywords gave students the opportunity to earn the bonus ribbons reserved for at-home video viewing. The second segment was the grand-finale spelling bee, in which students competed on the curriculum vocabulary emphasized across prior sessions, providing a final low-stakes assessment of NOS terminology mastery.

(8) Session 8—Career Mentorship and Recognition Event

The eighth session was a closing career-mentorship and recognition event held after the seven instructional sessions had concluded. Its purpose was twofold: to expose students to STEM role models through informal discussions with aviation and medical mentors about training pathways and day-to-day work, and to formally recognize student participation and progress through the distribution of program prizes and awards. This session was not used for instruction or assessment.

3. Results

3.1. Sample and Group Composition

Of the 72 fifth-grade students at the Title I site, 11 (15.3%) were invited into the SL after-school program based on their status as the lowest-performing students on weekly classroom assessments; the remaining 61 (84.7%) received the school's standard exam-preparation curriculum. All 11 invited students elected to participate (100% opt-in). Group assignment was therefore non-random and reflected pre-existing performance differences; this is acknowledged as a source of selection bias and is treated as a significant limitation. As described above, permission was obtained from parents and school officials.

3.2. Science FCAT Outcomes

Twenty-two of the 72 students (30.5%) passed the Science FCAT. Six of those 22 (27%) were SL participants. Within each group, 6 of 11 SL students (55%) and 16 of 61 non-SL students (26%) passed the Science FCAT. Mean scores on the NOS section were nearly identical across groups (SL = 5.63; non-SL = 5.59). Given the small SL sample (n = 11) and the non-random group assignment, formal hypothesis testing of group differences was not pursued. Results are reported descriptively, and the difference in NOS means should be interpreted as numerically minimal rather than as evidence of equivalence or superiority. Outcomes are summarized in **Table 2**.

Table 2. Descriptive comparison of Science FCAT outcomes for SL and non-SL groups.

Outcome	SL Group (n = 11)	Non-SL Group (n = 61)	Combined (n = 72)
Science FCAT, passing (%)	6 (55%)	16 (26%)	22 (30.5%)
NOS section, mean score	5.63	5.59	—
Session attendance	100%	<50%	—

3.3. Exploratory Linear Regression

To explore the relationship between performance on the NOS subsection and the overall Science FCAT score, a separate ordinary least-squares linear regression was fitted within each group, with NOS score as the predictor and Science FCAT score as the outcome (**Table 3**). The standard parametric assumptions for this model were considered: (i) a linear relationship between NOS and FCAT scores, (ii) approximately normally distributed residuals, (iii) homoscedasticity of residuals across the range of NOS scores, and (iv) independence of observations. Inspection of the data was consistent with these assumptions for the larger non-SL sample. The same model was fitted for the SL group (n = 11), but the small sample size limits statistical power and widens the confidence intervals around the slope and intercept; any apparent group difference in slope should be treated as exploratory rather than confirmatory.

Table 3. Group specific linear regression fitted models.

Cohort Groups	Fitted Line Formulas	Implied Fitted NOS Score
Non-SL students (n = 61)	FCAT score = 0.2696 + 0.3428 × NOS score	7.97
SL students (n = 11)	FCAT score = 0.0354 + 0.4292 × NOS score	6.91

Setting each fitted equation to the FCAT passing threshold (a score of 3) yields an implied NOS score of approximately 7.97 in the non-SL group and 6.91 in the SL group. Read descriptively, this indicates that within these data SL participants reached the same FCAT pass threshold at a lower implied fitted NOS score than non-participants. The slope estimate was numerically larger for the SL group than for the non-SL group, but no formal between-group test of slopes was conducted because of the limited SL sample. The fitted lines are shown in **Figure 6**; they should be interpreted as descriptive summaries of these data and not as evidence of an instructional effect.

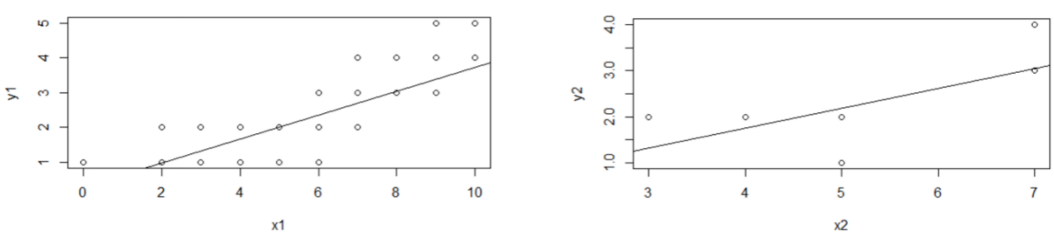

Figure 6. Group-specific linear regressions of Science FCAT score on Nature of Science (NOS) score. Left: non-participants (n = 61); fitted line FCAT = 0.2696 + 0.3428 × NOS. Right: SL participants (n = 11); fitted line FCAT = 0.0354 + 0.4292 × NOS. Lines are descriptive within-group summaries.

3.4. Teacher and Principal Satisfaction

Teacher and principal perceptions were collected to evaluate the feasibility, classroom fit, and educator acceptability of the curriculum conversion, not to estimate any effect of the program on student learning. A 13-item questionnaire was administered immediately at the end of the program to all five fifth-grade teachers and to the school principal. Items used a five-point agreement scale (strongly agree, agree, disagree, strongly disagree, not applicable) and addressed perceived classroom success, alignment with state standards, student engagement and interest, and willingness to reuse or recommend the curriculum. The instrument was designed by the school's science coach to capture impressions on items considered strategic for incorporating the program into future curriculum. It was developed for this study and was not independently validated; this is noted as a limitation. Responses are summarized in **Table 4**.

Table 4. Teacher satisfaction questionnaire: Percentage of respondents at each agreement level.

Item (n = 5 Teachers/Principal)	Strongly Agree	Agree	Disagree	Strongly Disagree
1. The program was highly successful in the classroom.	40%	60%	—	—
2. The students will do well on future standardized tests.	40%	60%	—	—
3. The students will perform better than other students who were not in the program.	40%	60%	—	—
4. The students' interest in science peaked because of the program.	80%	20%	—	—
5. Using an interactive teaching model is more effective than using a standard model.	80%	20%	—	—
6. The curriculum worked well with the state standards.	40%	40%	—	—
7. I am likely to recommend this program to other teachers.	60%	40%	—	—
8. This program will make my students more likely to pursue a STEM career.	40%	40%	—	—
9. I can see this program being implemented in future lesson plans.	60%	40%	—	—
10. This program enhanced my students' critical-thinking skills.	40%	40%	—	—
11. I would like this program implemented in next year's science curriculum.	60%	40%	—	—
12. This program generated more engagement from the students.	80%	20%	—	—
13. The program increased student awareness and interest in science and healthcare careers.	80%	20%	—	—

Across the 13 items, all five teachers and the principal selected "strongly agree" or "agree", except for six, eight, and ten, on which 20% (one of five teachers) wrote in "not applicable." This was noted because the teachers had not received the science FCAT and NOS performance report. No respondent selected "disagree" or "strongly disagree" for any item.

3.5. Attendance

Both the SL program and the school's standard remedial program were voluntary. Across the eight after-school sessions, attendance was 100% in the SL group and below 50% in the standard remedial group.

4. Discussion

This study examined an elementary STEM teaching intervention focused on curriculum design, instructional methods, student performance, and technology-enhanced learning tools. The standardized content was deconstructed and reconstructed using pop-culture media as instructional anchors. The intervention used music videos, video games, drones, and surgical simulation within a multisensory pedagogical model. The novelty of these tools is not the contribution of this work; the contribution lies in the design specifications of a multisensory pedagogical framework, which offers a template for customized curriculum creation and supports future studies with greater methodological rigor. The SL pedagogy and its converted curriculum are grounded in established research and incorporate validated knowledge-transfer elements: multisensory content, hands-on small-group station work, frequent exams, competitions, rewards, and mentoring.

4.1. Multi-Sensory Based Content

The traditional text-based curriculum was converted into customized music videos. Music in the classroom has been associated with increased engagement [64], and listening to music with a specific category of information has been associated with better recall of that information [65]. Rhythms with a steady beat have been linked to increased neurological stimulation and improvements in memory, awareness, literacy, and mathematical skills [66]. Music has been associated with the release of several neurotransmitters, including dopamine, which supports focus, and with elevated endogenous steroids, neurogenesis, and brain-derived neurotrophic factor (BDNF); BDNF in turn has been linked to improved spatial and auditory learning [67]. To draw on these neurophysiological effects, the main teaching points of the content were isolated and scripted into knowledge-transfer packets, with music selected for each video. Modern popular and rap music feature steady-beat consistency, which has been associated with these neurological responses.

Video use in classrooms has been linked to increased student engagement, particularly for English language learners [68], and video media has been associated with improvements in learning readiness and information recall [69]. The SL music videos are distinguished by combining music with infographics that include congruent scripted text, pictorial repetition, and continuous movement—features that have been linked to knowledge transfer and higher-order thinking [70]. Images with abbreviated, redundant text are processed faster than words and are more likely to be retained in long-term memory [71]. Interactive videos that allow repetition and pauses have been associated with greater learning gains than non-interactive videos [72]. The SL pedagogy incorporates these features.

4.2. Hands-On, Small Collaborative Groups Working in Stations

Students performed repetitions of the TGBD exercise using the Top Gun Training Simulator [73]. Consistent with the SL pedagogy, the students did not perceive themselves as practicing math skills while tracking bean counts and charting results; the math was embedded in the activity. The exercise also offered an entry point for exploring medicine and surgery as a career. Validated video games have been associated with knowledge and skill transfer in minimally invasive surgery [74,75]. *Super Monkey Ball*, used in this study, has been linked to increased non-dominant-hand dexterity, improved visual-spatial compensation, and enhanced targeting [76]. Unmanned aerial robotic vehicles (drones) offer an additional platform for developing hand-eye coordination and fine motor skills. All laboratory activity in the base curriculum was restructured around small-group stations using these tools. The HB drone exercise was used to develop scientific method and math skills by formulating an approach to determine maximum lifting capacity and charting results. The HB exercise, paired with the drone VR simulator, also exposed students to career-relevant skills in an emerging field. Small-group work has been associated with greater knowledge retention and higher-order thinking relative to independent work [77], and with stronger interpersonal relationships in the classroom and gains in critical thinking [78]. In each small-group activity, every student rotated through defined roles contributing to the completion of the exercise and to team building.

4.3. Frequent Exams, Competition and Rewards

SL also coordinates conventional curriculum enhancers—frequent exams, competition, and rewards. Weekly examinations have been associated with grade improvements of up to 12% relative to monthly examinations [79,80]. The program incorporated CBL, which has been associated with greater learning and student engagement, and recognized strong performance with stickers that counted toward end-of-program prizes. Combined extrinsic and intrinsic rewards have been associated with greater motivation to participate, learn, and succeed [81]. The reach of this education asset goes beyond primary education. Ruggiero et al. reported that CBL improved knowledge and skill acquisition in minimally invasive surgery [82].

4.4. Mentorship

Medical students and the surgeon SL curriculum-conversion specialist mentored students and assisted with program administration. Mentorship has been well received by students and parents and has been associated with improved academic performance [83,84]. Three forms of mentorship were used in this project: teacher-to-student mentorship, which supports problem-based learning and literacy acquisition [85]; peer-to-peer mentorship, which provides emotional support, supports self-esteem and confidence, and supports knowledge transfer, skill development, and social networking [86]; and professional mentorship, which has been associated with greater student interest in the related field [87].

The SL program also features CIL, which has prior academic validation in surgical education. Minimally invasive surgery uses small instruments, video cameras, and monitors to perform advanced procedures through 5–10 mm incisions without direct hand contact with the patient's organs, and is associated with less pain, fewer complications, and faster return to work. Using a physical surgical simulator with gamification features (light and buzzer activated by errors), validated video games, and virtual drone flight simulations, the SL pedagogy reduced the time required to acquire the cognitive and physical skill sets for minimally invasive suturing from 350 h to 12 h. This work was initiated in the 1990s [74,88–90]. CIL may merit broader use when addressing persistent performance gaps in education.

5. Conclusions

This pilot feasibility study assessed whether a remedial STEM curriculum could be converted and delivered in a classroom setting with attention to curriculum design, instructional pedagogy and methods, technology-enhanced learning tools, student standardized-exam performance, teacher satisfaction, and student attendance. The SL enhancement of the remedial lesson plans was successfully developed and implemented within the same time allotted for the standard program. The SL group had a higher Science FCAT pass rate (55% vs. 26%) and scored marginally higher than non-participants on the NOS section, although the NOS difference was not statistically significant. To examine why the SL group passed the Science FCAT at a higher rate, a linear regression model relating NOS performance to Science FCAT score was fitted in each group ($n = 61$ and $n = 11$). The linear regression was chosen for its ability to model the relationship between a scalar outcome and one or more predictors. Based on the fitted models, non-SL students required an implied NOS score of 7.965 or higher to be associated with passing the overall FCAT (passing score ≥ 3), whereas SL students reached the same threshold at an implied NOS score of 6.907 or higher. One possible but unproven explanation is that the NOS subsection is strongly associated with core science reasoning, so that even at a lower implied NOS score, the SL group had a stronger foundational grasp of the concepts. The SL curriculum may also have provided passive-learning elements that supported critical thinking, with potential carry-over to other Science FCAT sections. The investigational design and statistical rigor were not of level one quality, and substantial limitations constrain the interpretation of the findings, including non-randomization, voluntary selection, single-site setting, selection bias, and a small sample. Any inferences should therefore be considered preliminary. However, it should be noted that the students in the SL group started with the poorest performance. This may provide additional context to these preliminary findings. Within these constraints, the SL curriculum conversion appeared to be feasible and assisted performance, well-received by the teachers and principal, and well attended. The improved attendance of the SL group may provide some preliminary evidence of the engagement capability of the SL program. Larger, more rigorously designed studies are needed before any definite performance-enhancement claims can be made.

Author Contributions

Conceptualization, J.C.R. and J.C.A.L.; software, J.C.A.L.; validation, J.C.R., J.C.A.L., F.M.L., E.Y., L.S. and H.J.; formal analysis, J.C.R., J.C.A.L., F.M.L., E.Y., L.S. and H.J.; investigation, J.C.R. and J.C.A.L.; resources, J.C.R. and J.C.A.L.; data curation, J.C.R. and J.C.A.L.; writing—original draft preparation, J.C.R., J.C.A.L., F.M.L. and E.Y.; writing—review and editing, J.C.R., J.C.A.L., F.M.L., E.Y., L.S. and H.J.; visualization, J.C.R., J.C.A.L., F.M.L., E.Y., L.S. and H.J.; supervision, J.C.R.; project administration, J.C.R.; funding acquisition, J.C.R. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement

The study was conducted in accordance with the Declaration of Helsinki. The program was approved by the Orlando school district administration, which authorizes school-based educational research of this kind. Because the program operated as a school-administered after-school enrichment activity using routine educational assessment data, it falls within the category of exempt educational practices in established settings as defined in 45 CFR §46.104(d)(1) [59]; formal Institutional Review Board (IRB) review was therefore not required, and no protocol code was assigned.

Informed Consent Statement

Informed consent was obtained from all subjects involved in the study. Written parental consent was obtained for all students who participated in the after-school intervention.

Data Availability Statement

Data will be made available on request.

Conflicts of Interest

The authors declare no conflict of interest.

AI Use Statement

During the preparation of this manuscript, the authors used ChatGPT (OpenAI) solely for language refinement. No AI tools were used for data analysis, interpretation, or generation of scientific content. All outputs were critically reviewed and edited by the authors. The authors take full responsibility for the integrity and accuracy of the work.

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