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S.C.I.C.E.V FEEDBACK SYSTEM: ADVANCING PSYCHOMOTOR DEVELOPMENT, SKILLS, AND TECHNIQUE IN VOLLEYBALL

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ABSTRACT

Aim/Purpose	This study aims to evaluate the effectiveness of a novel Computerized System for Learning, Correction, and Evaluation in Volleyball (S.C.I.C.E.V) in enhancing the technical performance of beginner volleyball players through immediate audio and visual feedback. The purpose is to determine whether real-time, detailed feedback improves the execution of the two-handed down pass technique more effectively than conventional training methods. By utilizing advanced sensor technology and systematic evaluations, this research seeks to establish a reliable and efficient methodology for correcting technical errors, accelerating skill acquisition, and promoting optimal motor learning in young athletes.
Background	Technical precision is essential in volleyball, particularly for beginners, where improper techniques can hinder long-term performance and increase injury risk. Traditional training methods often rely on delayed feedback, limiting their effectiveness in correcting errors promptly.

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The S.C.I.C.E.V introduces an innovative approach using wireless sensors to provide real-time audio and visual feedback. This technology enables immediate error detection and correction, promoting faster and more accurate skill acquisition.

This study aims to validate S.C.I.C.E.V's effectiveness in reducing technical errors and enhancing the two-handed down pass technique in beginner volleyball players, comparing its outcomes to conventional training methods.

Methodology The study involved 60 beginner-level athletes (mean age 10.5 ± 1.2 years, sports experience 1.48 ± 0.504 years) from Club Sportiv Arcada Galati, evaluated by three tests using the computerized system S.C.I.C.E.V, which showed that immediate and detailed feedback (audio and video) improves the technical performance of beginner volleyball athletes compared to conventional training methods. Statistical analyses were performed using S.P.S.S. (Version 26). Using multivariate statistics, MANOVA assessed differences by feedback (between subjects) and testing time (within subjects). Assumptions were checked with Mauchly's and Levene's tests, and univariate analyses explored detailed effects and interactions.

Contribution In analyzing feedback in motor learning, an advanced learning and correction system in volleyball is presented, utilizing ten sensors on the arms, which are protected and wirelessly connected to a computer. The computerized learning, correction, and evaluation system consists of 10 sensors: 5 on the right and 5 on the left. Cuffs and harnesses protect the sensors and measure different sizes, providing data on ball contact on the forearms of the player, equality or inequality of the forces exerted by the ball on the player's forearms, level of the upper limbs concerning the shoulder, condition of the elbow joint, and grip of the palms during execution. The data acquired in this way is transmitted remotely (maximum 20 meters) wirelessly to the computer. The software on the computer performs a real-time data analysis and sends a voice response to the player to provide correction.

At the end of the training session, the coach will have a statistic of correct and wrong executions and can find out the segment in which the execution is deficient. Most importantly, the player can self-correct after each message heard. This paper contributes to the body of knowledge by introducing an innovative and practical system, S.C.I.C.E.V, for enhancing technical learning in volleyball. The understanding of real-time feedback mechanisms (audio and visual) in motor learning is advanced by providing a detailed framework for integrating sensor technology into training. The study highlights the effectiveness of immediate feedback in improving performance, offering an evidence-based methodology for technical correction and self-regulation in beginner athletes.

Findings The study demonstrated that the use of the S.C.I.C.E.V system significantly improved the technical execution of the two-handed down pass in beginner volleyball players. Athletes who received real-time audio and visual feedback showed marked reductions in technical errors compared to those trained with conventional methods.

Recommendations for Practitioners Practitioners are encouraged to incorporate real-time feedback systems, such as S.C.I.C.E.V, into volleyball training programs to accelerate skill acquisition and minimize technical errors. Sensor-based evaluations should provide detailed and actionable feedback, enabling immediate corrections and long-term development. To maximize the effectiveness of such systems, practitioners should ensure that the training environment supports the practical application of advanced technologies by offering the necessary infrastructure and guidance.

Recommendations for Researchers
Researchers are advised to focus on refining the S.C.I.C.E.V system by designing more compact, user-friendly, and cost-effective sensors to improve usability and accessibility. Longitudinal studies should be conducted to assess the long-term impact of real-time feedback on performance improvement and injury prevention. Additionally, researchers should investigate the psychological effects of immediate feedback on athlete motivation and engagement to enhance the overall effectiveness of these systems.

Impact on Society
Integrating systems like S.C.I.C.E.V into sports education highlights the transformative potential of technology in skill development. Enhancing technical precision and reducing errors can lead to more effective learning experiences for young athletes while reducing the risk of injuries and fostering lifelong engagement in sports. These advancements contribute to developing inclusive, efficient, and motivating training environments, ultimately improving the quality of youth sports programs and supporting broader efforts to promote active and healthy lifestyles.

Future Research
Future research should focus on further refining the S.C.I.C.E.V system by developing more minimalist and user-friendly sensors to enhance practicality and accessibility in training environments. Additionally, exploring the system's application across different volleyball techniques and other sports could broaden its impact. Longitudinal studies could also evaluate the sustained benefits of real-time feedback on performance and injury prevention, ensuring the system's effectiveness over extended periods and diverse athletic levels.

Keywords
audio-feedback, visual-feedback, sensors, psychomotor, technical correction, volleyball

INTRODUCTION

The device presented in this article, the Computerized System for Learning, Correction, and Evaluation in Volleyball (in Romanian: Sistem Computerizat de Învăţare, Corectare şi Evaluare în Volei – S.C.I.C.E.V), was developed to address the need for an objective assessment method and to assist in the correction of technical errors in beginner volleyball players. Specialists believe that execution mistakes are an integral part of the learning process. For the successful acquisition of knowledge and progress, it is essential to be aware of the mistakes that occur even at the beginner level. The absence of advanced training equipment and correctional technologies for beginner volleyball players represents a significant gap in the developmental pipeline, as elite-level teams benefit from cutting-edge devices and software designed to monitor, evaluate, and optimize performance.

While high-performance teams employ sophisticated tools for tracking and assessing technical execution, the lack of accessible technology for teaching and correcting fundamental skills at the beginner level hampers the systematic cultivation of talent. The disparity between evaluation-focused equipment available for beginners and the state-of-the-art learning aids utilized by professional teams underscores the need for innovative solutions that bridge this technological gap in skill acquisition and refinement. Modern training devices are an effective way of assessing the players' performance, which helps in the methodology of preparation and progress.

This paper extends previous research (Pârvu & Rosculet, 2014) by demonstrating the importance of new software for analyzing and correcting the execution of the two-handed passing/taking down technique in training small volleyball players in Romania. Proper assessment in sports is essential for monitoring progress and identifying areas for improvement. Another article (Pârvu et al., 2011) highlighted how, through accurate assessments, coaches can provide specific and targeted feedback that contributes to optimization in volleyball. Additionally, removing technique errors during the learning phase of motor action learning is crucial for providing a solid foundation in athlete training. The literature and scientific articles on the subject reveal the need to find ways of teaching volleyball to beginners, as learning technical procedures requires numerous ball-handling actions; in response, the authors of the study (Nieves et al., 2018) developed a prototype for a sensor-based Smash Athlete volleyball skills testing tool. The research results suggest that the Sensor Technology Smash Volleyball Testing Tool is considered adequate and reliable for measuring smash volleyball skills. Overall, the study demonstrates the tool's validity, reliability, and potential as a valuable tool for assessing and improving smash volleyball skills (Komaini et al., 2022).

Assistive devices allow for immediate assessment and self-assessment during execution, prompting an instant response from the user and creating constant feedback between the user, device, and teacher. The assistance devices used at initiation must allow integration into structures and sets of actions that support the continuity of the exercises, focus on the preparation of the complete action, emphasize the dominant aspects, facilitate integration into the phases of play, favor specific biomechanical and motor aspects, prevent the occurrence of individual technical or tactical errors and comply with the regulations in force.

Another study highlighting the need for assessment tools to adapt to modern times presents the importance of innovation in the assessment process' content and presentation style for developing a sensor-based volleyball passing skills test. The findings argue that easy-to-use and properly implementable testing tools are needed to measure passing technique in volleyball (Indrakasih et al., 2022).

Correcting errors early prevents the reinforcement of incorrect patterns and helps develop correct and practical skills. Shortening the learning time by correcting techniques promptly allows athletes to progress faster and achieve superior performance in a shorter time. Timely and correct interventions facilitate the correct assimilation of movements and reduce the time required to master them. Continuous technique correction ensures that performance is maintained and improved. Athletes who receive constant feedback and technique correction can adjust and refine movements, leading to superior performance and reduced injury risk.

Oculomotor coordination in volleyball involves the complex integration of visual and motor inputs, enabling players to anticipate ball trajectories and execute the precise movements required for effective shots and strategic placements. Fine and gross motor control skills are essential for performance in volleyball, where the correct execution of jumping, diving, and hitting techniques requires precise synchronization of muscle movements and rapid postural adjustment to maintain balance. Reaction speed in volleyball is a critical indicator of psychomotor efficiency, requiring an ability to quickly process external stimuli and initiate appropriate motor responses in an intense game dynamic.

Spatial orientation and three-dimensional perception play a pivotal role in volleyball, allowing athletes to estimate distances and angles accurately, thus facilitating strategic placements and coordinated defensive interventions. Concentration and distributional attention are vital determinants of volleyball performance, influencing players' ability to maintain a high focus during matches and make quick and accurate tactical decisions under competitive pressure.

Proper assessment is essential for monitoring athletes' progress and identifying areas for improvement. A study by Palidis and Fellows (2024) emphasizes the importance of accurate and regular assessments to provide specific and targeted feedback, thus contributing to the optimal development of sports skills. Eliminating technique errors in the learning phase of motor action is crucial for the correct training of athletes. According to research by Gheorghe et al. (2022), early correction of errors prevents the formation of wrong patterns and helps develop correct and efficient movements.

Shortening learning time by correcting technique promptly allows athletes to progress faster and achieve superior performance in a shorter time. Studies by Indrakasih et al. (2022) and Komaini et al. (2022) show that timely and correct interventions facilitate the correct assimilation of movements and reduce the time required for mastery.

Continuous technique correction is essential to maintain and improve performance. One study (Bill et al., 2024) highlights that constant feedback and technique corrections help athletes adjust and refine movements, leading to superior performance and reducing the risk of injury. Correct assessment and technical correction contribute to competent and confident athletes. According to Ciorbă and Moroşan (2012) and Zhao (2022), prompt identification and correction of errors builds confidence in athletes' abilities and better prepares them for competition.

A practical technical assessment and correction system supports athletes' physical and mental development. The studies by Bourne and Foster (2024), Jansen et al. (2025), and Naima et al. (2020) emphasize that accurate corrections and constructive feedback improve motor skills, self-assessment, and adjustment skills, which are essential for long-term success in sports. Consistent and correct feedback during training sessions significantly improves sports performance. Johnson et al. (2020 and Mihai et al. (2024) have emphasized that regular and specific feedback helps athletes understand and correct errors faster, leading to improved performance in competition.

According to research (Blegur, 2019; Ciocan et al., 2023; Harabagiu, 2020; Larionescu & Pacuraru, 2011; Neculai & Carmen, 2022), removing technical errors in the learning phase contributes to making movements more efficient and reducing the effort required to perform motor actions correctly, which is essential for developing high-level sports skills. The studies by Ali and Kazmi (2024) and Pârvu et al. (2023) show that real-time technical adjustments based on accurate assessments are essential for strengthening correct and efficient motor skills. These adjustments allow athletes to correct errors and immediately avoid forming wrong patterns. Technique correction improves performance and is crucial in injury prevention (Ali & Kazmi, 2024; Yu et al., 2018). These have shown that athletes who receive regular technique correction have a reduced risk of injury due to the correct execution of movements and avoidance of postures that can cause injury.

Constructive feedback and prompt correction of techniques positively impact learning and motor memory (Bisagno et al., 2020; Burlui et al., 2021; Musculus et al., 2019; Ogasa et al., 2024; Olaru, 2024; Teodora-Mihaela & Mihaela, 2017). Studies have shown that feedback given immediately after the execution of a movement contributes to the strengthening of motor memory and long-term skill improvement.

Correct assessment and technical correction contribute to competent and confident athletes. By promptly identifying and correcting errors, athletes develop confidence in their abilities and are better prepared to face competitive challenges. A practical technical assessment and correction system supports athletes' physical and mental development. Accurate corrections and constructive feedback improve motor skills, self-assessment, and adjustment, which are essential for long-term success in sports. Studies demonstrate that accurate assessments and consistent feedback lead to better confidence, precise execution, and enhanced competitive readiness in athletes (Abbas & Nsaif, 2023; Lee et al., 2022; Zhao, 2022).

In contrast to the advanced training and correction systems available in elite volleyball, the reliance on evaluation-oriented equipment at the beginner level highlights a critical technological shortfall in nurturing foundational skills. Modern software and devices used in high-performance volleyball provide precise monitoring and feedback, yet their absence in beginner training programs limits the potential for early detection and correction of technical errors.

LITERATURE REVIEW

Modern training devices are an effective way of evaluating players' performance that helps in the methodology of training and achieving progress.

One study's (Bisagno et al., 2020) results cement the idea of finding and using educational software in physical education or volleyball training lessons. However, in high-performance teams, advanced movement analysis devices and software (Harabagiu, 2020; Yan & Yang, 2023) are used in real-time during matches or analysis sessions, where the efficiency of the game of their players or even of their opponents is monitored (Ungurean & Puni, 2019; Voinea et al., 2021). In novice volleyball, there is a lack of modern devices that provide objective evaluations. In Romania, a series of materials have been patented to help teams prepare for volleyball, but they do not provide objective evaluations; they only help to understand and train the basic mechanics of the movement. In the tendency to promote this sports game, only educational programs such as Teaching Games for Understanding (TGfU) appear, which is a pedagogical model based on the game to encourage decision-making and in-depth understanding of the game (Badau et al., 2023; Bisagno et al., 2020; James et al., 2023). A study conducted on 121 novice sportswomen aged 10–12 highlights new ways to achieve progress in volleyball by using apps, creating their website to inform sportswomen, using sketches, 3D animations, videos, and point lectures (Kioumourtzoglou et al., 2022). Also, for evaluation, we developed motivation and satisfaction questionnaires, and here again, they obtained significant results for the female athletes who were part of the experimental group compared to those in the control group.

Documented studies show correlations between fitness indicators and basic motor skills in novice teams (9–10 years). The results are insignificant; at this age, anthropometric indicators and mastery of essential technical elements are not dependent (Stefanov, 2021). The invasion of technology has fundamentally changed the way of learning in many fields, and a brief literature search indicates that multimedia's influence on the training of children's teams is also evident.

The use of multimedia in sports and physical education increases the potential of students' understanding of movement learning through multiple information channels and audio-video, thus eliminating multiple technical errors (Gunawan et al., 2019). Advanced technologies, such as wearable sensors and data analysis through machine learning, can provide coaches and players with accurate, real-time insights into technical and physical performance, thereby transforming the way football training sessions and matches are managed (Kos et al., 2018).

In Romania, there are only two systems known to be suitable for volleyball beginners groups, which help to learn and provide an objective evaluation of movement analysis: the DIRPAS-NS2006 system (Mirela & Valeria, 2012) used for consistency and accuracy in execution and the first version of the system proposed 10 years ago by Pârvu and Rosculet (2014). The proposed system aligns with the technology emerging worldwide and represents a novel element in the country, where volleyball is still taught in a more simplistic manner. It serves as a modern and attractive training tool that provides real-time feedback and objective assessments. Through an experimental study, this research highlights the usefulness of execution analysis and correction software for the two-handed low pass/kick technical procedure, as well as the importance of real-time audio and video feedback in coaching groups of children in volleyball.

In Ukraine, a study examining children's training in volleyball, basketball, and tennis (Sushko & Ibraimova, 2015) shows that it is crucial to apply techniques and means of study adapted to children's age, level of physical development, and physical condition to learn and develop the necessary skills in these sports. Innovative technologies, defined as sets of methods and means supporting innovation processes, such as introduction, training, consultancy, and transfer, are essential (Das et al., 2022; Neag et al., 2024; Rada, Amzar, & Niculescu., 2024; Vişan & Cojanu, 2020). The use of multimedia technology in learning and training can overcome the limitations of space, time, and distance, facilitating access to information and instruction interactively and effectively. In sports, multimedia technology can develop interactive programs that support training and improve athletes' performance (Suhairi et al., 2020), producing regular or real-time progress statistics. The MEMS sensor-based monitoring device, developed and implemented in volleyball by other researchers, has demonstrated a remarkable ability to assess the skill levels of volleyball spikers. By classifying spikers into three different levels using support vector machines based on recorded data, the system achieved an average accuracy of 94%. The results presented from the research suggest that the device can be a valuable tool for coaches and players in assessing and improving performance (Wang et al., 2018).

As in the research presented above, sensor-based wearable devices are considered to offer advantages in terms of cost and computational power required, thus opening new directions for sports research and training (Gheorghe et al., 2024; Wang et al., 2018). In physical education and sports, feedback is crucial in enhancing student development by providing constructive insights that guide improvement in psychomotor skills, coordination, and overall performance (Moisescu & Burlui, 2019). Whether in athletic training or classroom learning, effective feedback helps students assimilate information, refine techniques, and achieve better results in their respective goals.

In conclusion, the research aims to better understand the needs and requirements in volleyball training and develop interactive and technological solutions to improve athletes' performance and learning processes in collective and individual training.

METHODOLOGY

The proposed hypothesis is that the use of the Computerized System for Learning, Correction, and Evaluation in Volleyball (S.C.I.C.E.V), which integrates audio and video feedback along with periodic, objective assessments provided by the analysis software, has a positive impact on improving technique and correcting technique errors in novice athletes. The hypothesis suggests that the audio and video correction messages transmitted in real-time through the system facilitate the understanding and correct application of volley techniques.

This feedback supports learning and optimizes athletes' performance by immediately identifying and correcting errors. Regular objective evaluations provided by the analysis software will demonstrate a correlation between the use of the S.C.I.C.E.V system and significant improvement in technical execution, reflected by a decrease in test errors.

PARTICIPANTS

The study involved 60 beginner-level athletes, aged between 10 and 13 years old, who were active at the Arcada Galati Sports Club, with sporting experience ranging from six months to two years. The mean age of the athletes was 10.5 years (±1.2), with a mean training period of 1.48 years (±0.504) and a mean level of training of 1.40 (±0.494). The participants were registered athletes from the Arcada Galați Sports Club, under the coordination of the study's first author, Pârvu Carmen. Athletes were fully informed about the following:

- The purpose and nature of the study;
- Practical details and potential risks involved;
- Their right to withdraw from the study at any time without repercussions.

Ethical procedures - consent and approvals

Written consent was obtained voluntarily from all participants' legal representatives (parents or guardians). Approvals were secured from:

- The Ethics Committee of the Galati Sports Club (Protocol 116/9.11.2022);

- The Human Performance Research Center Ethics Committee is affiliated with the Faculty of Physical Education and Sports, Dunărea de Jos University of Galati (Protocol 196/12.06.2024).

Participant selection and training:

- Careful selection of participants ensured compliance with ethical standards.
- Necessary agreements from legal representatives were obtained to guarantee proper and ethical implementation.
- Compliance with ethical standards.

The study ensured:

- Adherence to international ethical research standards (Declaration of Helsinki);
- Complete transparency regarding the study's nature, risks, and participant rights; and
- Approval from relevant ethical committees underscoring its validity and integrity.

Three tests were conducted to assess the progress and effectiveness of learning: initial, intermediate, and final. The test was conducted using a computerized system for volleyball learning, correction, and evaluation. Each test contains ten executions performed with the S.C.I.C.E.V machine, separate from the game, which evaluates the execution technique of the two-handed down pass, showing mistakes in a palm grip, incorrect bending of the elbows, lifting the fist or uneven application of force on the forearms. Depending on the errors found, the software evaluates and scores a series of 10 executions. After each execution, the software issues a correction voice message and highlights the mistake in red in the table.

Athletes who asked for immediate and detailed feedback from the computerized system, including audio and video feedback, obtained better results than athletes who did not ask for real-time feedback but only for the test score after the ten runs. This allowed the evaluation of the direct impact of technology on the performance and correction of technical errors in novice volleyball, providing a clear comparison between the benefits of technological feedback and conventional training methods in this specific context of youth volleyball.

The Organization of the Research

The system presented in this paper was integrated into 96 training sessions conducted over nine months, from January 2023 to September 2023. The S.C.I.C.E.V system was used to evaluate the two-handed down pass technique. Each athlete used the system for 20 minutes per session, with audio or video feedback, depending on preference. Wireless headphones were used for the athletes who opted for audio feedback, for those who opted for visual feedback, and for the projection of the software-generated error table. All performers received a graded evaluation after the series of tests.

The coach threw 10 balls from a distance of 6 meters to the athlete undergoing the test. The ball had to be returned to the coach. After each execution, the athlete released their hand grip and returned to the waiting position for the next ball. All sessions were monitored to ensure procedural consistency. After each series of 10 executions, athletes received an objective evaluation through a score generated by the S.C.I.C.E.V software.

The research included three primary assessments:

1. *Initial testing:* To evaluate each athlete's baseline level.
2. *Intermediate testing:* To track progress made during the training sessions.
3. *Final testing:* To assess the results and overall impact of the S.C.I.C.E.V technology on the athletes' performance.

This methodological organization allowed for the collection of objective and relevant data, providing a solid foundation for analyzing the impact of technology use in youth sports training.

The statistical analysis of data

Statistical calculations were performed using S.P.S.S. (Statistical Package for the Social Sciences - Version 26). MANOVA was used to assess whether significant differences exist between groups created by between-subjects factors (feedback) and between different levels of within-subject factors (testing time). Multiple multivariate statistics were calculated to test the significance of the effects of feedback. Sphericity tests (Mauchly's Test) and homogeneity of variances tests (Levene's Test) were conducted to validate the assumptions required for MANOVA. Univariate analyses were performed in detail to explore the effects of feedback and its interactions with each testing time.

Content Implementation of Computer System Design for Learning, Assessment, and Correction in Volleyball

Overall, the system used in our research represents a sophisticated integration of technology and sports training, aiming to provide athletes with a practical and interactive method of improving volleyball techniques. The device is designed to monitor the athlete's movements while executing the "two-handed underhand pass" technique, a highly rapid and complex process requiring fine control over all body movements. The system was conceptualized and developed based on the technical errors observed during the initiation stage of the underhand pass in volleyball practice with beginner athletes.

The movement of the arms is essential for the correct placement of the ball, and the coordination between mobilizing the scapulohumeral joints and adjusting the forearm angles plays a crucial role in directing the ball's trajectory. Controlled flexion and extension of the shoulder joint and maintaining the forearms in slight pronation allow the ball to be struck with high precision, dynamically adjusting the direction and force needed for each pass. In volleyball, the speed of execution is critical, and any delay in correcting errors can result in losing control of the ball. By providing real-time feedback, the system helps athletes understand and correct technical errors, thereby improving the efficiency and accuracy of their execution.

System operation and calibration

Specific steps must be followed to set up and operate the S.C.I.C.E.V system to ensure proper configuration and optimal equipment functionality. These steps include correctly mounting the components, initializing the dedicated application, and performing the necessary calibration to obtain accurate and reliable data. The process is designed to facilitate system use even for less experienced operators while ensuring the efficiency and reliability of the measurements obtained (Figure 1).

Before testing the device, rigorous calibration is essential to ensure the accuracy and reliability of measurements. Calibration involves a series of initial adjustments that enable the device to capture the athlete's movements and provide accurate feedback. This process includes verifying and configuring the sensors with high precision to record relevant parameters (such as arm angles and joint movements).

Also, calibration may involve establishing reference values to compare the data collected during testing. These reference values should be derived from controlled and repeatable movements performed by an athlete with the correct technique, ensuring the device can detect and correct potential technical errors during the realistic execution of the exercises.

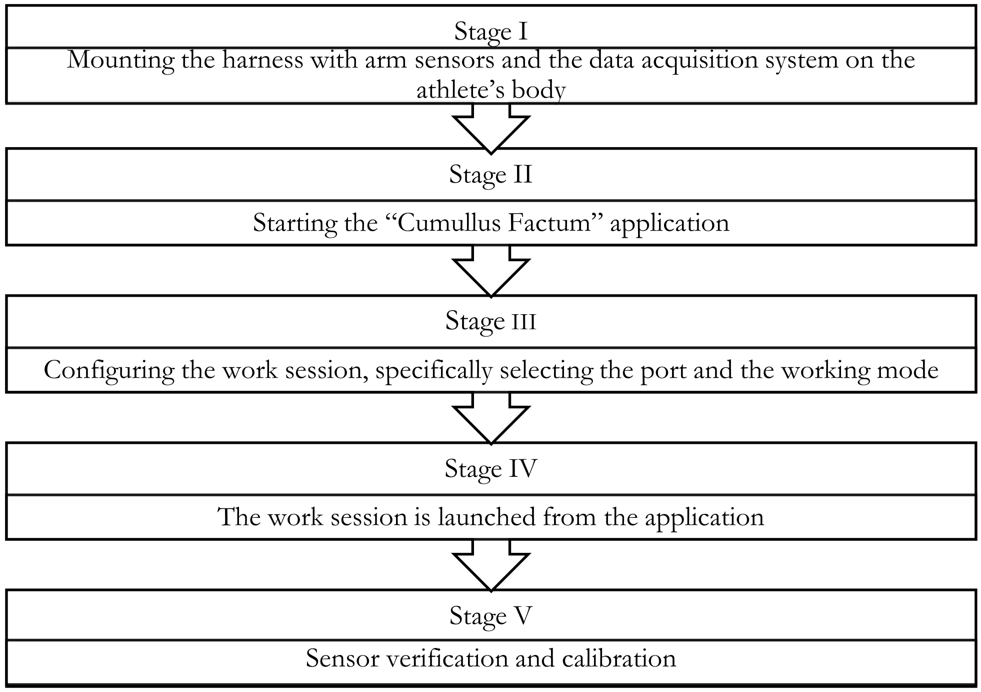

Figure 1. System operating mode

After mounting the sensors on the athlete's arms, the data acquisition system on the belt, and starting the work session, each sensor is checked to ensure it responds correctly in the table shown in Figure 2 to the stimuli or actions for which they are positioned on the arms (Figure 3):

1. The grip sensor; (6)
2. The sensors for punch detection; (3)
3. The sensors measuring the ball strike force measurement on the arm; (1)
4. The sensors for strike position on the arms; (2)
5. The sensors measuring arm level; (5)
6. The elbow flexion sensors (4).

Unlike the other sensors, the elbow flexion sensors must be calibrated by adjusting the value of the variable resistor RV4, as shown in Figure 3 (Horizontal deviation sensors (5)). The calibration should be done so that, with the elbow fully extended, the LED on the formation circuit located on each arm is off, while at an elbow flexion more significant than 10-15°, the LED lights up.

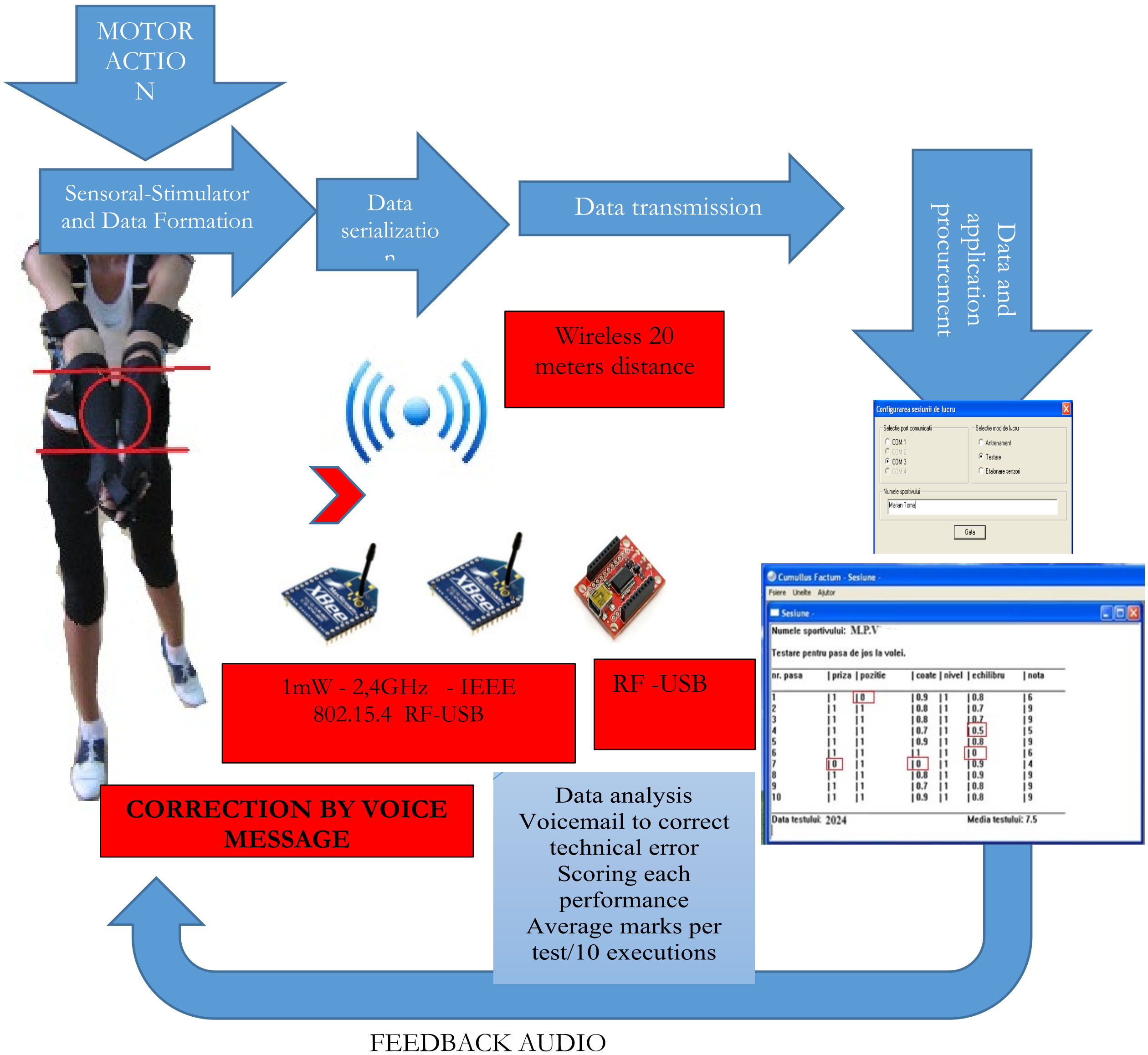

Figure 2. Hardware components of the system for learning, correction and assessment at the two-handed low-pass

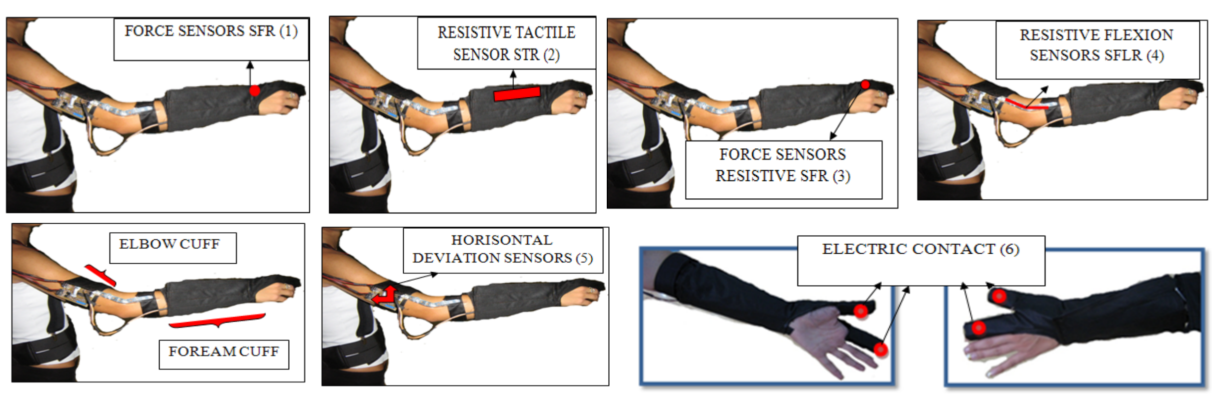

Figure 3. Position of the sensors on the forearms

The system's centerpiece adjusts movements and techniques based on feedback for optimal performance. Sensors and signaling circuitry are mounted on the arms and forearms, and they detect and measure the athlete's movements in real time, providing precise data about the athlete's position and movement (Figure 3).

Through the feedback provided by the system, the athlete adjusts their movements and technique to achieve optimal performance. The system integrates advanced data processing and transmission mechanisms, enabling seamless collection, serialization, and wireless transfer of real-time performance metrics from the athlete to the central processing unit, facilitating precise analysis and actionable feedback. The components detailed in Table 1 illustrate the structural and functional architecture of the S.C.I.C.E.V. system, highlighting its capacity to capture, transmit, and analyze performance data in real time to support athlete development.

Table 1. Key components of the system for feedback in volleyball (S.C.I.C.E.V)

1. Athlete as the central element • The athlete is the system's core, actively interacting with the components. • Feedback from the system allows the athlete to adjust movements and techniques for optimal performance.
2. Sensors and signal-forming circuits • Location: Mounted on the athlete's arms and forearms. • Functionality: Detect and measure real-time movements, including: ✓ Acceleration ✓ Velocity ✓ Position ✓ Tilt angle • Data transmission: Collected data is sent to the processing unit embedded in specially-designed sleeves.
3. Serialisation module • Purpose: Converts sensor data into a serial format. • Benefit: Ensures smooth and efficient transmission to other system components.
4. Wireless data transmission • XBee 1mW modules (2.4GHz): ✓ Compliant with IEEE 802.15.4 standard for efficient wireless communication. ✓ Facilitates data transmission up to 20 meters. ✓ Setup: ▪ One module on the athlete's arm. ▪ Another module is connected to the computer.
5. XBee explorer USB • Role: Receives wireless data from the XBee modules and transfers it to the computer.
• Connection: Acts as an intermediary using a USB interface.
6. Real-time data processing and feedback • Computer system: ✓ Receives and processes transmitted data. ✓ Evaluates player performance in real-time, tracking each pass for precise feedback.

The computer performs several essential functions, including storing and analyzing collected data, evaluating the athlete's technique and performance in real time, and providing appropriate auditory feedback via a speaker connected to its sound interface. Voice feedback can range from encouragement to specific instructions, depending on the quality and correctness of the technical execution.

The data is transmitted wirelessly to a computer (up to 20 meters), which analyses it in real time and gives the player corrective voice feedback. The system detects six execution mistakes and sends eight voice messages: 6 for correction, 1 for appreciation of correct execution, and 1 for signaling more than two simultaneous mistakes.

Vocal feedback, given through a speaker connected to the computer, provides ratings such as "Very good!", "Pass with the thirds of your arms!" "Elbows out!" "Hit with both hands!", "Incorrect grip!", "Punches down!". If two mistakes are made simultaneously, the software issues the message: "Wrong step!".

Overall, the system we used in our research represents a sophisticated integration of technology and sports training, aiming to provide athletes with an efficient and interactive method of perfecting their volleyball technique.

RESULTS

Table 2 presents the descriptive data for the means and standard deviations of the scores obtained by the athletes in three different tests (first test, intermediate test, and final test) based on the presence or absence of visual and audio messages after each execution. Data are organized by message category (none, visual, audio messages), with totals provided for each test. The table underscores the critical role of visual and audio feedback in enhancing performance, showcasing significant differences in averages and variability across feedback types. Additionally, the results suggest how feedback influences performance trends over time, highlighting improvements attributable to visual and audio prompts.

The data indicate that visual and audio feedback significantly impact athletes' performance, with mean scores consistently higher for those receiving feedback than those who did not. The trends reveal a steady improvement across tests for groups receiving feedback, while the absence of feedback corresponds to minimal change over time.

Table 2. Descriptive statistics
The effect of visual and audio messages on athletes' performance in tests

Feedback type	Mean	Std. Deviation	N
Grades first test			
No visual or audio message	6.2000	0.76112	30
Visual message after each execution	7.9000	0.78807	20
Audio message after each execution	8.2000	0.63246	10
Total	7.1000	1.17459	60
Intermediate test grades			
No visual or audio message	6.0667	0.58329	30
Visual message after each execution	8.7500	0.55012	20
Audio message after each execution	8.8000	0.63246	10
Total	7.4167	1.47627	60
Grades final test			
No visual or audio message	6.0333	0.76489	30
Visual message after each execution	9.0500	0.68633	20
Audio message after each execution	8.9000	0.73786	10
Total	7.5167	1.66206	60

For instance, in the first test, the group receiving audio messages achieved a mean score of 8.20 compared to 7.90 for visual messages and only 6.20 for the group without feedback. In the final test, visual feedback yielded a mean of 9.05, slightly outperforming the group with audio feedback (8.90). The group without feedback remained static, with a mean score of 6.03.

Standard deviation analysis highlights reduced variability in performance for groups receiving feedback compared to those without. For example, in the intermediate test, the standard deviation for the group without feedback was 0.58, higher than 0.55 for visual and 0.63 for audio feedback. This consistency suggests that feedback improves average performance and promotes more uniform outcomes across individuals.

Implementing visual and audio motivational messages can be considered an effective strategy to improve students' academic performance, with a slightly higher effectiveness of audio messages. Based on these results, it is recommended to integrate these types of messages into the educational process in order to maximize students' potential. Table 3 presents the analysis of the sphericity hypothesis in the study of the effect of feedback on test performance.

Table 3. Mauchly's test of sphericity for within-subjects effect

Within subjects effect	Mauchly's W	Approx. Chi-square	df	Mr.	Epsilon[b]		
					Greenhouse-geisser	Huynh-Feldt	Lower-bound
Test	0.952	2.746	2	0.253	0.954	1.000	0.500
Tests the null hypothesis is that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.							

a. Design: Intercept + feedback; Within Subjects Design: testing
b. May be used to adjust the degrees of freedom for the averaged significance tests. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Mauchly's Test of Sphericity confirmed that the assumption of sphericity was met for the within-subjects design (Mauchly's W = 0.952, $\chi^2(2) = 2.746$, $p = 0.253$). This suggests that the error covariance matrix is proportional to an identity matrix, supporting the uniformity of test score variability across experimental conditions. While adjustments for degrees of freedom using Greenhouse-Geisser ($\varepsilon = 0.954$) and Huynh-Feldt ($\varepsilon = 1.000$) methods were minimal, they provide a robust check for significance testing.

This result indicates that the assumption of sphericity is not violated, ensuring the validity of within-subject comparisons without requiring substantial corrections. The lower-bound epsilon ($\varepsilon = 0.500$) serves as a conservative adjustment for degrees of freedom in the case of severe violations of sphericity. However, given the p-value above 0.05, this adjustment was unnecessary in the present analysis.

Meeting the assumption of sphericity indicates that the variability in differences between conditions is consistent, ensuring the reliability of statistical comparisons across testing conditions. The Greenhouse-Geisser ($\varepsilon = 0.954$) and Huynh-Feldt ($\varepsilon = 1.000$) corrections, while available as robustness checks, confirm minimal deviations from sphericity, indicating that the results are unlikely to be influenced by violations of this assumption.

By confirming sphericity, the analysis validates the consistency of observed effects across feedback conditions, suggesting that any differences are not artifacts of irregular data variability. This finding strengthens the reliability of conclusions drawn from the study and supports the validity of feedback as a variable influencing performance.

Multivariate tests showed that the type of feedback (no feedback, visual prompts, or audio prompts) significantly impacted student performance (Table 4). About 28.3% of the variation in scores was due to the type of feedback.

Table 4. Multivariate tests summary for within-subject effects

Effect		Value	F	Hypo-thesis df	Error df	Mr.	Partial eta squared
test	Pillai's Trace	.283	11.070[b]	2.000	56.000	.000	.283
	Wilks' Lambda	.717	11.070[b]	2.000	56.000	.000	.283
	Hotelling's Trace	.395	11.070[b]	2.000	56.000	.000	.283
	Roy's Largest Root	.395	11.070[b]	2.000	56.000	.000	.283
testing * feed-back	Pillai's Trace	.357	6.202	4.000	114.000	.000	.179
	Wilks' Lambda	.643	6.906[b]	4.000	112.000	.000	.198
	Hotelling's Trace	.553	7.599	4.000	110.000	.000	.217
	Roy's Largest Root	.550	15.678[c]	2.000	57.000	.000	.355

a. Design: Intercept + feedback; Within Subjects Design: testing
b. Exact statistic
c. The statistic is an upper bound on F that yields a lower bound on the significance level.

The interaction between the test type and feedback was also significant, meaning the effect of feedback depended on the specific test. These results were consistent across all tests, confirming the reliability of the findings.

Univariate tests revealed significant differences in mean scores across feedback types. Performance improved in the following order:

- No Feedback: Mean scores decreased over time (T initial =6.20, T intermediate = 6.07, T final = 6.03).
- Visual Feedback: Scores consistently increased (T initial = 7.90, T intermediate = 8.75, T final = 9.05).
- Audio Feedback: Scores showed moderate improvement (T initial = 8.20, T intermediate = 8.80, T final = 8.90).

The interaction effects further emphasized that the impact of feedback was contingent on the type of test, with visual feedback yielding the most significant gains in performance across testing conditions. Partial Eta Squared values for the interaction ranged from 0.179 to 0.355, indicating that this interaction explained a substantial portion of the performance variability. Feedback significantly influenced academic performance, with visual feedback demonstrating the highest effectiveness. These results underline the importance of tailored feedback mechanisms in educational interventions. The consistency of effect sizes and significance across multivariate tests affirms the reliability of these findings. In conclusion, feedback significantly affected student performance, with the most significant improvements observed in those who received visual messages.

Figure 4 shows the effectiveness of visual and audio feedback on academic performance: analysis of estimated marginal means.

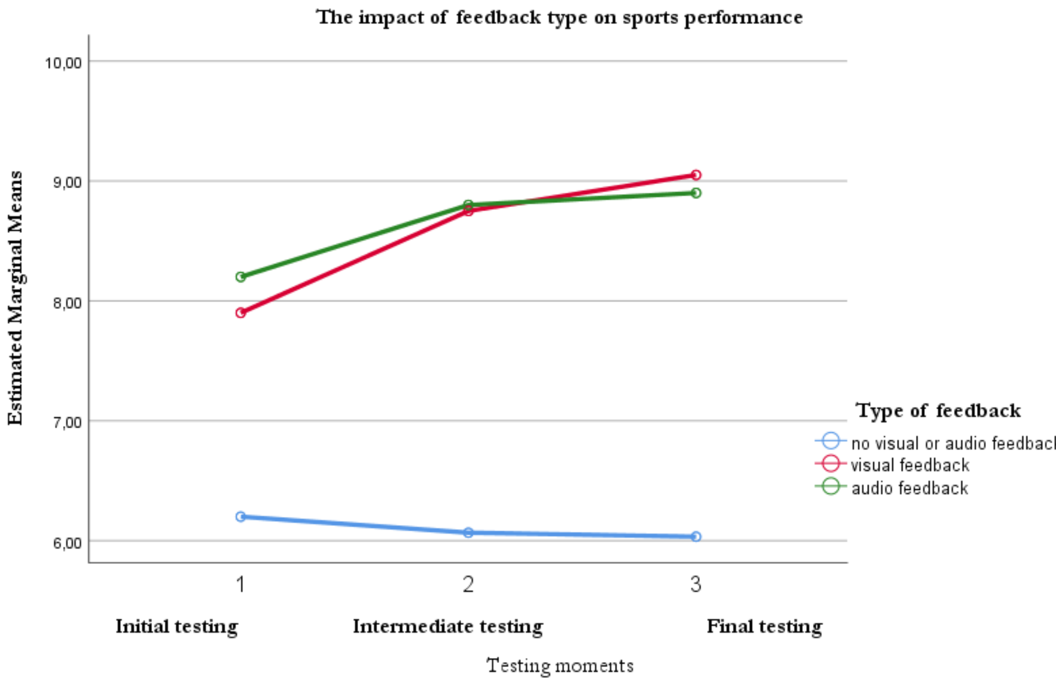

Figure 4. The evolution of athletes' performance based on feedback type and testing moments

The graph shows a significant increase in scores for students who received visual or audio prompts after each execution compared to those who did not. For both the group with visual messages (red line) and the group with audio messages (green line), there is a steady increase in grades from the first test to the final test, indicating that these types of feedback have a positive and sustained effect on academic performance.

The blue line, representing students without visual and audio prompts after each execution, shows consistent but significantly lower performance across all three trials. This suggests that the lack of motivational feedback does not improve students' performance, keeping them at a constant low-performance level compared to the other groups.

In earlier stages of testing, audio feedback had a slightly higher impact than visual feedback, likely because 10-year-old students are more responsive to auditory stimuli, associating audio messages with immediate praise and encouragement. According to cognitive load and sensory processing theories, younger students process auditory feedback more effectively, which reduces cognitive strain and supports better information retention. As students mature in their understanding of feedback, they gradually focus on visual cues, especially as they develop a more precise mental representation of motor actions. This transition highlights how their growing cognitive abilities and familiarity with feedback mechanisms influence their engagement with different types of feedback.

Throughout the three tests, the differences in performance between students who received visual messages (red line) and those who received audio messages (green line) become minimal, especially at the midterm and final tests. This suggests that although audio messages initially appear to have a slight advantage, both messages are equally effective in improving students' academic performance in the long run.

DISCUSSION

The findings of this study align with the conclusions of Krause (2017), which highlighted that visual and audio feedback can significantly enhance students' academic performance. This study examines the impact of mastery experiences with technology, vicarious experiences, and social persuasion on the self-efficacy of physical education student teachers in integrating technology during their teaching practice. Sixty participants (32 women and 28 men) completed the Computer Technology Integration Survey for Physical Education before and after their teaching practicum. The results revealed a significant increase in the student teachers' self-efficacy in integrating technology into physical education, with positive correlations observed between their technological experiences and their self-efficacy.

Both works emphasize the importance of feedback and technology in the learning process. In *Multimedia Learning* (Mayer, 2009), key concepts regarding how interactive and technological tools enhance comprehension and retention through effective feedback mechanisms are discussed. Similarly, Mayer's (2011) chapter from *The Psychology of Learning and Motivation* focuses on how applying the science of learning in a multimedia context improves student engagement and performance through tailored feedback and technological support. In both studies, students exposed to motivational messages demonstrated a steady increase in grades, emphasizing the importance of feedback as a learning tool.

The findings indicated that audio messages had a slightly more substantial effect than visual messages on academic performance, a result similar to those of Ding et al. (2022), who found that auditory feedback may be more effective in improving information retention due to the auditory channel being less overloaded compared to the visual channel. More minor standard deviations for students who received feedback indicate a more uniform performance, a result supported by the study of Han et al. (2022), which showed that feedback can reduce variation in student performance, helping all students to achieve higher levels of proficiency.

The results align with the studies by Bisagno et al. (2020) and Ryan and Deci (2000), emphasizing the importance of feedback in increasing students' intrinsic motivation. In both studies, visual and audio feedback positively impacted motivation and, thus, academic performance.

The significant increase in midterm and final test scores observed in our study is consistent with the research of Blegur (2019) and Rada, Amzar, Amza, and Cojanu (2024) which showed that immediate and consistent feedback during the learning process could lead to continuous improvements in student performance.

The study supports the results of other research that emphasizes the importance of feedback in promoting self-regulated learning. The authors showed that effective feedback helps students monitor and adjust their learning strategies, leading to superior academic performance. This type of feedback encourages students to become independent and self-regulated learners (Hijazi, 2020).

The results, which show an improvement in academic performance, align with recent studies such as the one conducted by Lipnevich and Smith (2009). These researchers have shown that constructive and specific feedback can reduce test-related anxiety and increase students' self-confidence, thus contributing to better academic performance. Feedback that provides detailed information about progress and tips for improvement can encourage students and reduce the stress associated with assessments.

The analysis has shown that immediate feedback has a more significant impact on both immediate and long-term performance than delayed feedback. These results are consistent with the studies of Hijazi (2020) and van der Kleij et al. (2015), which showed that immediate feedback allows students to correct mistakes in real time, reinforcing learning and reducing the likelihood of repeating mistakes.

The survey highlights the benefits of adaptive and personalized feedback for students. The studies of Bahadirovna (2023), Tashpulatov (2024), and Veenman et al. (2006) support these findings, emphasizing that adaptive feedback that considers individual student needs can significantly improve performance and motivation. Personalized feedback helps to identify weaknesses and provide specific advice for improvement.

The investigation confirms that negative feedback can be as valuable as positive feedback when offered constructively. Ali and Kazmi (2024) emphasized that negative feedback can stimulate growth and learning, provided it is offered in a way that encourages reflection and improvement. Feedback should be specific and offer straightforward suggestions for remediation.

The present study supports research demonstrating that feedback can positively influence students' intrinsic motivation. For example, Ogasa et al. (2024) and Ryan and Deci (2000) have shown that feedback focusing on effort and progress rather than outcomes can enhance intrinsic motivation and commitment to learning. Feedback that recognizes effort and improvement may encourage students to continue to engage in learning actively.

The findings confirm that feedback plays a crucial role in collaborative learning. The studies of Dumitrache and Almăşan (2014), Gielen et al. (2010), and Radu et al. (2024) revealed that constructive feedback in teamwork can improve group performance and foster a collaborative learning environment. Moreover, the analysis of academic data using advanced methods, such as those described in SPEET (Barbu et al., 2018), demonstrates how classifying students based on explanatory variables enables the personalization of feedback, the anticipation of academic outcomes, and the support of self-regulated learning.

Effective feedback in learning teams promotes open communication, conflict resolution, and collective skill enhancement. These additional studies support the idea that feedback can significantly impact students' academic performance, self-regulated learning, motivation, and collaboration when properly structured and implemented.

LIMITATION

The study focused on a relatively small sample of 60 beginner volleyball players from a single sports club, limiting the generalizability of findings. Participants were homogeneous in age and experience, which may not reflect the diversity of athletes across different age groups, skill levels, and cultural contexts.

The primary evaluation focused on the immediate effects of the S.C.I.C.E.V system on skill acquisition and technical performance. Long-term impacts, such as sustained performance improvement, skill retention, or injury prevention, were not explored, limiting the understanding of the system's effectiveness over time.

The research concentrated solely on the two-handed down pass technique, narrowing the scope of findings. The effectiveness of the S.C.I.C.E.V system in improving other volleyball techniques or broader sports applications was not assessed.

Implementation of the S.C.I.C.E.V system requires access to advanced sensor technology and supportive infrastructure, which may not be feasible or accessible in all training environments. This reliance on technology might restrict applicability in under-resourced or outdoor settings.

While highlighting the benefits of immediate audio and visual feedback, the study does not address potential psychological drawbacks, such as over-reliance on feedback, reduced intrinsic motivation, or stress caused by continuous error correction. Further research is needed to evaluate these factors and their impact on athlete development.

The S.C.I.C.E.V system is compared to conventional training methods, but its performance is not evaluated against other modern or sensor-based feedback systems. This omission limits the ability to determine whether S.C.I.C.E.V offers unique advantages over existing technologies.

Testing occurred in a controlled environment with a maximum wireless range of 20 meters. This setup may not reflect real-world training conditions, such as larger courts, outdoor environments, or competitive match settings, where system performance and practicality could differ.

Although the S.C.I.C.E.V system provides detailed feedback and statistical analysis, the study assumes coaches have the expertise to interpret and act on data effectively. Variability in coaching skills or familiarity with the system could influence the effectiveness of diverse training programs. The device was not used during the bilateral game; testing was conducted only in isolation at the net, not during the game itself.

CONCLUSIONS

In conclusion, the study demonstrates that integrating visual and audio feedback after each performance has a profound and transformative impact on students' academic progress. For the main effect of testing, all multivariate tests indicated a significant effect ($p < 0.05$). For the interaction between testing and feedback, all multivariate tests indicated a significant effect ($p < 0.05$), with Partial Eta Squared values between 0.179 and 0.355, indicating significant variability explained by the interaction between testing and feedback. The plot of the estimated marginal means showed a significant increase in scores for athletes who received visual or audio prompts, indicating a positive and sustained effect of these types of feedback on performance. The complete analysis, including Mauchly's Sphericity Test and multivariate tests, confirms the validity and methodological robustness of the results. The assumption of sphericity was not violated, allowing interpretation of the results without major adjustments of degrees of freedom. The multivariate tests indicate a significant effect of both the variable 'test' and the interaction 'test-feedback,' reinforcing the conclusion that the type and frequency of feedback significantly influence academic performance. This emphasizes the importance of implementing visual and audio feedback and the need to use rigorous statistical methods to assess the impact of educational interventions. Analysis of descriptive statistics and multivariate tests show that students exposed to these messages experienced a significant increase in grades across the three tests. This emphasizes the effectiveness of these feedback methods in improving academic performance and suggests that such interventions can create a more motivating and effective learning environment, fostering continuous learning and self-regulation.

The study demonstrates that visual and audio feedback significantly improve academic performance. Across all three tests, students who received feedback consistently outperformed those who did not. For example, in the final test, students without feedback had an average score of 6.03, while those with visual feedback scored 9.05, and those with audio feedback scored 8.9.

Key statistical analyses confirmed significant effects for the test type and the interaction between test type and feedback ($p < 0.05$). The interaction between testing and feedback explained 17.9% to 35.5% of the variability in performance, highlighting the substantial impact of feedback.

The results also showed a clear trend: students with feedback improved steadily from the first test (visual: 7.9, audio: 8.2) to the final test (visual: 9.05, audio: 8.9). Visual feedback had the highest overall impact, but both types of feedback proved highly effective.

This analysis confirms that implementing visual and audio feedback creates a motivating environment, leading to consistent improvement in performance and supporting continuous learning.

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