

Design and Preliminary Functional Evaluation of an ESP32-Based Interactive Hockey Training Board

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ABSTRACT

Interactive hockey training equipment can coordinate visual cues and electronic event recording, but functional integration alone does not establish measurement validity or training effectiveness. This article presents a retrospective engineering account of an ESP32-based interactive hockey training board using a final-year project report as its sole experimental source. Its contribution is the consolidation of dispersed implementation details, identification of discrepancies between documented firmware and performance interpretations, and explicit separation of completed functions from unresolved validation requirements. The prototype combined nine illuminated dribbling targets, three ramp-goal targets, infrared sensors, local controls, a liquid-crystal display, and TCP-based desktop monitoring. Source inspection recovered GPIO assignments, the stated power-supply rating, target-selection and event-counting logic, and difficulty-dependent switching intervals. A companion supplement makes these details and their source locations available while identifying missing specifications. The difficulty-summary dataset comprised 34 repeated sessions involving one participant: 14 easy, 13 medium, and seven hard sessions. Reported mean hits per minute were 44.40, 58.55, and 48.51, with standard deviations of 27.94, 20.93, and 17.40, respectively. These values describe source-reported session variation rather than independently verified device performance. Visual cueing, sensor-triggered events, local interaction, and desktop monitoring were documented qualitatively. Automatic ball return was unsuccessful: controller resets persisted after same-model servo replacement, and the final configuration required manual retrieval. Response-time, accuracy, and fatigue interpretations were excluded because the available documentation did not validate them. No additional experiments or independent measurements were performed. The article improves the transparency of the implementation record without establishing full reproducibility, measurement accuracy, or training benefit. Controlled event-counting, communication and storage tests, complete construction specifications, and documented participant-testing arrangements remain necessary before stronger conclusions can be drawn.

Keywords: field hockey; interactive training board; ESP32; infrared sensing; prototype evaluation.

INTRODUCTION

An interactive training board must coordinate the presentation of a task with the detection and recording of a player's response. For hockey, this creates an engineering problem involving ball movement, target placement, visual cues, sensing, and feedback. A working interface can demonstrate that these components communicate, while the validity of the resulting performance measures requires separate evidence. This distinction determines what can be concluded from an early prototype.

Electronic cues and sensing are established elements of hockey assessment. Sunderland et al. (2006) described a hockey skill test incorporating a light stimulus and infrared-triggered timing. Tapsell et al. (2022) evaluated a hockey-specific dribbling speed test using a defined protocol and players from different competitive levels. Lemmink et al. (2004) investigated repeated sprint and dribble testing in young hockey players. Together, these studies motivate explicit validation of a test and its protocol; their findings cannot be transferred directly to a

new device. Light-cued training has also been studied in basketball using FITLIGHT equipment (Hassan et al., 2022). That adjacent-sport evidence does not demonstrate a benefit from the present hockey board.

The source project developed a compact arrangement of illuminated targets, infrared sensors, an ESP32 controller, and a desktop interface (Faizrul bin Pitalaung, 2026). Its intended functions included dribbling exercises, a ramp-based goal task, and automated ball return. Converting this development report into an engineering article requires separating documented operation from proposed functions and from measures whose validity remains uncertain. In particular, successful detection of programmed target events is insufficient to establish accurate measurement of human reaction time or improvement in hockey skill.

The article adds an organized engineering reconstruction to the original development report, rather than a new experimental dataset. It consolidates the GPIO map, power-supply description, target logic, difficulty settings, and evidence locations in Supplement S1; distinguishes the final manual-retrieval configuration from the planned return mechanism; and corrects interpretations that the printed counters and inconsistent summaries cannot support. This makes the design record easier to inspect and identifies precisely what another researcher would still need to reproduce it. A focused comparison in Section 4.1 situates the design among interactive training arrangements described in the source report. No new sensing principle, comparative performance advantage, or training effect is claimed.

METHODS

Study design and evidence boundaries

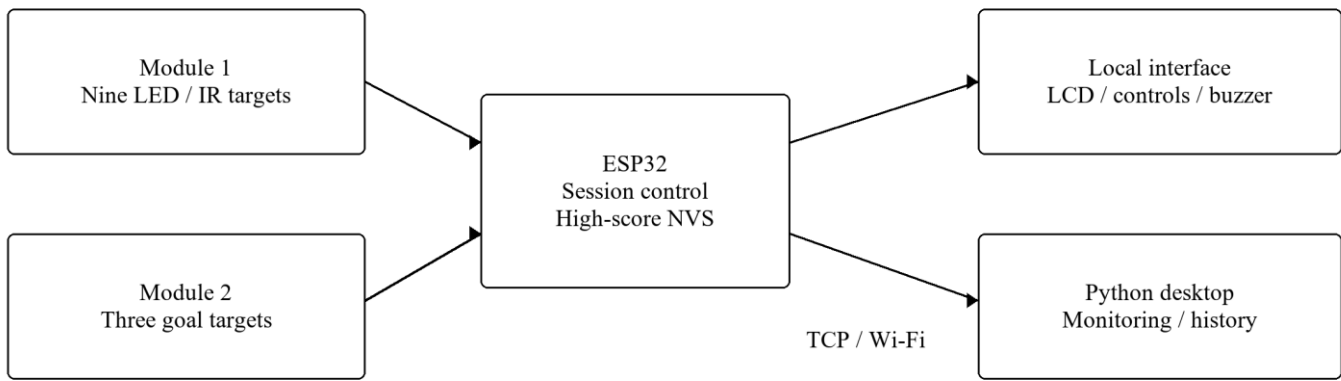
The original work was an engineering development project with a single-participant functional evaluation. The present revision uses the original report and the submitted article as documentary inputs; it adds no experiments, participants, or independently verified measurements. The report's narrative, figures, summaries, and Appendix A listing were cross-checked to recover implementation details and assess which outcomes could be reported (Faizrul bin Pitalaung, 2026)..

The report describes indoor laboratory testing and indicates that easy sessions occurred initially while the participant became familiar with the system. It does not supply a complete ordering of the 34 sessions, the participant's prior hockey experience, rest intervals, or independently timed session durations. Figures and aggregate tables do not constitute a complete session-level dataset. The reported export capability does not establish that an export has been preserved; no such file was available for this revision. These omissions constrain interpretation of the difficulty summaries.

Hardware architecture and recoverable construction details

The ESP32 DevKit V1, mounted on an expansion board, coordinated a nine-target dribbling module (Module 1), a three-goal ramp module (Module 2), WS2812B LED rings, a 20×4 LCD, four buttons, and a passive buzzer. Module 1 used a 3×3 arrangement with an infrared obstacle sensor associated with each illuminated station. Module 2 placed sensors beneath or behind the three goal openings within partitioned ball channels. The report identifies plywood construction and an artificial-grass surface, but provides no dimensioned drawing from which board size, target spacing, ramp angle, or sensor mounting coordinates can be reliably reproduced. The infrared sensor manufacturer and model are also unspecified.

Figure 1 remains a functional overview. The documented signal allocation is explicit: Module 1 sensors 1–9 map to GPIO32, 33, 34, 35, 25, 26, 27, 14, and 12; Module 2 sensors 1–3 map to GPIO17, 18, and 19. LED data use GPIO5; LCD SDA and SCL use GPIO21 and 22; the buzzer uses GPIO2. Start, mode, difficulty, and reset buttons use GPIO4, 15, 16, and 23, respectively. Supplement S1 provides this mapping as a connection schedule, not a verified circuit schematic.



Final configuration: manual ball retrieval; servo return removed

Figure 1. Documented functional architecture and final configuration. Arrows indicate logical interfaces, not individual electrical connections. Redrawn from the source report.

The hardware-integration figure labels the external switching supply as 5 V, 20 A DC, and the narrative describes regulated 5 V distribution through terminal blocks to the peripherals. This is a reported supply rating, not a measured operating current or a verified load budget. Regulator, protection, decoupling, grounding, and signal-level interface details are insufficient to reconstruct the complete electrical circuit. No unverified connections have been added to make the design appear complete. Table 1 summarizes the documented subsystems; the planned MG996R return servo was removed from the final configuration.

Table 1. Prototype components and documented roles.

Subsystem	Components / interface	Documented role and status
Dribbling module	Nine LED / IR targets	Visual targets and detected ball events; source-reported operation.
Ramp module	Three goal targets	Goal task arrangement; manual retrieval in final configuration.
Local controller	ESP32; LCD; controls; buzzer	Session control and feedback; high-score NVS in printed code.
Desktop interface	Python; TCP over Wi-Fi	Monitoring and separately reported history; no measured transfer reliability.
Return mechanism	MG996R servo	Removed after resets; automatic return not achieved.

Target selection, event counting, and difficulty settings

The printed program distinguishes Random, Rapid, and Sequence modes for Module 1. Random and Rapid select a new target different from the current target after an accepted event. Sequence begins at index zero and advances modulo nine. Rapid additionally changes the active target after a difficulty-dependent interval. Easy, medium, and hard use configured session durations of 60, 45, and 30 s; their Rapid switching intervals are 1800, 1200, and 750 ms, respectively. Module 2 uses the same configured session durations and target-switching intervals of 2000, 1300, and 800 ms. In the inspected listing, these timed switches are subject to the Module 2 release/cooldown state. Difficulty therefore changes exposure time and, in Rapid or Module 2 operation, the target-switching schedule. A comparable timed switch was not identified for Module 1 Random or Sequence modes.

Module 1 evaluates the active target using a three-sample digital filter with 500 μ s delays; at least two samples must match its configured trigger state. An accepted event increments both score and totalAttempts and sets a hit lock. The lock is released when the sampled target is clear or through a timeout branch after sustained activation. This describes the code's handling of repeated input, not a demonstrated duplicate-rejection rate. HPM is calculated as score divided by configured duration in minutes. Because score and totalAttempts increase together, their ratio does not provide an independent accuracy measure.

Module 2 samples each goal five times, with 500 μ s delays, and accepts at least three LOW samples under the implemented integer threshold. A detected active goal increments the correct-event count; another goal increments the wrong-event count. A 200 ms cooldown and a release-wait branch with a 2000 ms timeout gate further processing. Events that never activate a sensor remain outside these counters. Supplement S1 provides structured pseudocode and relevant code locations. These descriptions concern the printed listing; the deployed version used for individual sessions cannot be confirmed.

The listing uses an ESP32 TCP client to send newline-terminated payloads to the desktop endpoint. Its send routine returns without sending when disconnected, and reconnect attempts are rate-limited to five seconds. These behaviors do not establish loss-free delivery, replay, latency, or agreement between sent and stored records. Desktop monitoring and history are reported separately from local storage. Preferences provides the ESP32 storage interface (Espressif Systems, n.d.-b), whereas NVS describes the underlying key-value storage (Espressif Systems, n.d.-a). The listing includes high-score storage and calibration-state persistence; it does not establish a complete persistent event archive. No fresh retention or interruption tests were performed.

Outcome eligibility and descriptive reporting

The retained numerical results are the source-reported Module 1 HPM summaries for 14 easy, 13 medium, and seven hard sessions. Means, standard deviations (SDs), and coefficients of variation (CVs) were transcribed without reconstructing raw observations. Their displayed arithmetic was checked for compatibility within rounding limits. No inferential tests, pooled estimates, or training-effect calculations were performed. Configured durations in Section 2.3 must not be substituted for unreported actual session durations.

Exclusions were decisions of the retrospective reporting audit. Quantitative response times were omitted because a screenshot and its accompanying table disagree. Accuracy percentages were omitted because the inspected Module 1 counting logic lacks an independent attempted-action denominator. Mode-level comparisons were excluded because session totals and table/chart values conflict with other summaries. Fatigue interpretations were excluded because neither the heuristic nor its physiological meaning was independently validated and the accompanying graph and prose disagree. Supplement S1 identifies the affected source locations.

RESULTS

Documented prototype and functional evidence

Figure 2 shows the assembled prototype. The source describes target illumination, sensor-triggered display changes, local controls, and updates in the desktop interface. These are qualitative development observations supported by photographs, screenshots, and narrative descriptions. They are not independently counted trials. No reference-versus-recorded activation series, missed-event count, duplicate-event count, or communication/storage reconciliation log was supplied. Accordingly, this article reports the functions as documented observations and does not assign a success rate or measurement accuracy.



Figure 2. Assembled prototype reproduced from the source report.

Difficulty-summary dataset

Table 2 reproduces the eligible source aggregates. The reported mean was highest for the medium setting, followed by hard and easy. This ordering is a description of the available summaries only. Different task settings, unequal session counts, an incompletely documented session sequence, and a single participant prevent attribution of the differences to difficulty alone. The session observations must not be treated as 34 independent participants.

Table 2. Source-reported Module 1 summaries by difficulty.

Difficulty	Sessions	Mean HPM	SD of HPM	CV (%)
Easy	14	44.40	27.94	62.94
Medium	13	58.55	20.93	35.74
Hard	7	48.51	17.40	35.87

Note. HPM = hits per minute; SD = standard deviation; CV = coefficient of variation. One participant contributed the 34 sessions in this difficulty summary. Values are transcribed source aggregates, not independently reproduced from raw data. SD and CV describe session variation. Source: Faizrul bin Pitalaung (2026).

The reported SDs and CVs describe variation among sessions in the source summary. Such variation may include player behavior, task conditions, and device behavior; the available data do not separate those contributions. The lower reported CVs for medium and hard therefore do not demonstrate greater instrument repeatability. The absence of event-level records also prevents independent reproduction of the aggregation, identification of excluded sessions, or examination of within-session patterns.

Automatic-return integration

The source describes controller resets during operation of the MG996R return servo. Same-model replacement did not resolve the problem, and the final configuration used manual retrieval. No measured electrical trace or controlled fault-isolation record establishes the cause. The report therefore does not demonstrate a sustained autonomous shooting-and-return cycle. Table 3 separates documented outcomes from the evidence still required to validate them.

Table 3. Functional outcomes and required further validation.

Function	Source-reported outcome	Further validation needed
Cueing and sensing	Illuminated targets and sensor events documented.	Independent event counts, false/missed detections, and timing reference.
Monitoring and storage	Desktop monitoring/history described; high-score and calibration storage in listing.	Transfer failures, persistence, and complete event-record checks.
Automatic return	Servo-associated resets; replacement unsuccessful; servo removed.	Electrical diagnosis and repeated return-cycle evaluation.
Performance measures	Difficulty aggregates retained descriptively.	Independent metric validation and prospective participant protocol.

DISCUSSION

Contribution relative to the original report and existing devices

The added value of this article is documentary and analytical: it brings implementation information dispersed across the report into an inspectable description, distinguishes code behavior from claims about human performance, and preserves the unsuccessful return integration. The connection schedule, difficulty settings, pseudocode, and evidence index in Supplement S1 are products of this reconstruction, not newly tested design files. They improve technical transparency while leaving the unreported construction details explicit.

The source report describes Game Changer as supporting light-cued drills with score/time feedback and SuperDeker as using sensors and LED targets for stick-handling on a low-friction surface (Faizrul bin Pitalaung, 2026). Table 4 compares those reported arrangements with the present board. These commercial descriptions are secondary accounts in the supplied report, not a current manufacturer survey or a direct experimental comparison. Features not described there cannot be assumed absent. The present board's combination of nine dribbling targets, three ramp-goal targets, and local/desktop interfaces is a particular implementation; the comparison establishes neither superiority nor cost advantage.

Table 4. Comparison of arrangements described in the original report.

System	Task and feedback described	Interpretive boundary
Game Changer	Light-cued drills with score/time feedback.	Secondary description in the source; no direct comparison test.
SuperDeker	Sensor-equipped stick-handling with LED targets on a low-friction surface.	Secondary description; unspecified features must not be assumed absent.
Present board	Nine dribbling targets, three ramp-goal targets, local and desktop interfaces; manual retrieval.	A particular integrated arrangement; no demonstrated performance or cost advantage.

Note. Commercial-device descriptions are secondary accounts in Faizrul bin Pitalaung (2026).

The previously cited hockey assessment and FITLIGHT basketball study provide broader precedent for electronic cues and recorded responses (Sunderland et al., 2006; Hassan et al., 2022). They do not validate this board. Its potential usefulness as an engineering report rests on making the implemented logic and evidence limits inspectable, rather than treating prototype operation as proof of training effectiveness.

Measurement interpretation

A target-response completion interval combines stimulus presentation, perception, movement, sensor activation, and software processing. Independent timing references and a validated protocol would be required to separate these contributions. Correcting a disagreement between displayed values alone would not establish a measure of isolated human reaction time.

In Module 1, the paired score and totalAttempts updates can produce a 100% ratio without recording missed physical attempts or erroneous detections. The available documentation therefore cannot establish an accuracy percentage or perfect performance. Module 2 distinguishes detected correct and wrong goals, but that distinction still does not independently count shots missed by the sensing system. Likewise, SD and CV across human sessions combine task, participant, and possible device variation; they do not isolate instrument repeatability. Previous hockey test-validation work motivates defined repeated-measurement procedures rather than transferring reliability estimates to this prototype (Lemmink et al., 2004; Tapsell et al., 2022). An increase in target-response completion time is not, by itself, a validated measure of physiological fatigue.

Remaining validation requirements

The single-participant summaries, incomplete session metadata, uncertain deployed firmware, and missing construction specifications limit reproduction and generalization. Source inspection cannot repair these gaps. The servo-reset mechanism also remains unresolved: the reported supply label does not show the voltage or current at the controller during a reset. Electrical diagnosis, rather than inference from component replacement, is required to distinguish possible causes.

Supplement S1 specifies prospective tests for independently counted target activations, prolonged and repeated inputs, communication interruption/reconnection, and separation of desktop storage from local high-score retention. These are proposed tests with empty result fields, not additional evidence or completed validation. A subsequent participant study would require documented consent and an appropriate institutional ethics determination, predefined outcomes, and a design capable of assessing training benefit. The original testing's ethics and consent status remains unresolved in the records available for this revision.

CONCLUSION

The source documents an ESP32 prototype integrating nine dribbling targets, three ramp-goal targets, local interaction, and desktop monitoring, with manual retrieval after unsuccessful servo-return integration. This article consolidates the recoverable design and firmware information and clarifies which recorded outcomes can be interpreted. The 34-session summaries remain descriptive observations from one participant. No new tests were performed, and full reproducibility, measurement validity, and hockey-skill improvement remain unestablished. Complete construction records and independently reconciled functional tests are needed before stronger operational or training claims can be made.

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