



Development and Acceptability of Chargeable Battery-Operated Soldering Iron Device

An Operation Guide

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ABSTRACT

This study developed a chargeable battery-operated soldering iron device and determined its level of acceptability to address unexpected power interruptions because it can be used without the presence of AC power. The study utilized a descriptive experimental approach since it developed a chargeable battery-operated soldering iron device. It was assessed with its specifications and functionalities. Survey questionnaires were used and distributed to the sixty respondents from CTU Daanbantayan Campus and San Remigio Extension Campus. It was found out that in terms of risk, perceived usefulness, perceived ease of use, attitude, and intention of use, the chargeable battery-operated soldering iron device was highly acceptable. However, respondents recommended decreasing the weight and size and putting the product in a box to make it more portable. When it comes to safety, it is also suggested to put an LED to indicate its ON/OFF status to avoid skin burns. Overall, the product was highly acceptable to be used as a soldering iron device. An operation guide was made for the users to be guided on how to use the product.

Keywords

Battery Operated Tools
Soldering Iron
TAM's Model
Technology Education

JETIA

Journal of Educational Technology Innovation and Applications

Vol. 2, No. 02, pp. 151-168

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Article history

Received 29 April 2026

Revised 4 May 2026

Accepted 14 June 2026

journal.iistr.org/index.php/JETIA
DOI: 10.56741/IISTR.jetia.002272



Introduction

The landscape of modern electronics is undergoing a transformative shift, driven by the rapid advancement of information technologies and the increasing demand for smarter, more integrated devices [1]. As the global market transitions from conventional manufacturing to high-power electronics and autonomous driving systems, the role of joining technologies—specifically soldering—has become a cornerstone of industrial reliability [2]. This evolution is not limited to traditional circuitry; it encompasses emerging fields that require high-density computing and real-time data processing, which in turn pose significant heat dissipation challenges [3].

Because these modern systems involve higher packaging densities and increased heat flux, the precision of the soldering process and the effectiveness of thermal management have become inseparable from the lifespan and functionality of electronic systems [1]. The integration of power electronics into large-scale renewable energy generation highlights a critical need for efficient and reliable power conversion stages [4]. Consequently, the development of specialized soldering tools, particularly those that are portable and low-cost, is no longer a localized concern but a global necessity for sustainable industrial growth and environmental efficiency [5].

Literature Review

A. Foundational Role of Ergonomics and User-Centric Design

The efficacy of soldering processes is fundamentally rooted in the synergy between tool design and thermal performance. Analytical solutions using differential equations in partial derivatives have demonstrated that the phenomenon of heat transfer is deeply influenced by the specific shape of the soldering iron. By applying the method of separating variables in cylindrical coordinate systems, researchers have successfully modeled how changing the geometry of a welding apparatus directly impacts temperature distribution [6]. This mathematical precision is essential for automated installations, such as those used in automotive glass manufacturing, where temperature stability is critical [7].

Beyond traditional manufacturing, this user-centric utility is evidenced in specialized clinical settings. Recent prospective studies have evaluated the use of electric soldering irons as ergonomic and cost-effective alternatives to traditional surgical tools like monopolar diathermy for partial mastoidectomy [8]. The results indicated that soldering irons can offer superior outcomes in terms of operative time and blood loss, proving that the portability and design of a soldering iron can redefine its "acceptability" across diverse professional domains.

B. Safety, Performance, and Physiological Advantage

Safety remains a paramount concern in soldering, particularly as operational personnel are exposed to sudden temperature changes exceeding 300°C, which can lead to significant health

symptoms [9]. The performance of these tools is also being challenged by environmental directives, such as the EU RoHS Directive, which standardized the use of Sn-Ag-Cu (SAC305) lead-free solder. Because SAC305 contains higher tin content, it causes rapid erosion of iron plating on soldering tips. Researchers are now investigating composite platings, such as iron combined with boron nitride (BN) compounds, to extend tool lifespan and maintain thermal efficiency [10].

Furthermore, the "physiological" performance of the solder joint is being revolutionized through nanotechnology [11]. Flux doping with iron nanoparticles (Fe-NPs) has been shown to improve the wetting properties of the flux and increase its viscosity, which is essential for maintaining joint integrity [12]. These nanoparticles have proven effective in inhibiting electromigration under prolonged high-current stressing, ensuring that solder pads remain robust even in high-density electronic environments.

C. Data-Driven Assessment and Digital Evaluation

As industries move toward Industry 4.0, the evaluation of soldering skills has shifted from single-factor models to multifactor digital frameworks [13]. Traditional models often focused solely on the holding method of the iron; however, modern research emphasizes heating time of the base metal and solder melting time as key metrics for skill transfer. Techniques such as parallel phase-shifting digital holography now allow for the precise imaging of temperature distribution around the soldering iron, providing a quantitative basis for training [14].

The lack of a established framework for quantifying soldering techniques is being addressed through haptic-based virtual training. By utilizing Long Short-Term Memory (LSTM) networks and time-series analysis, researchers can analyze soldering motions in a virtual space. This allows for the transmit of power generated in virtual environments to a physical manipulator, creating a safe and measurable educational environment for trainees before they handle live equipment [15].

D. Cognitive and Behavioral Integration in Usability

The "human element" in soldering is increasingly managed through cognitive science and behavioral monitoring. Because soldering is a repetitive task prone to "corner-cutting" and lack of concentration, new indicate systems have been developed for danger detection. These systems utilize object detection and posture estimation to detect dozing states or inattentive postures, which is particularly vital for the inclusive employment of persons with disabilities [15].

To further enhance usability, researchers are integrating 3D stereoscopic capture with Augmented Reality (AR) glasses like the HoloLens 2 [16]. By estimating the user's line-of-sight and providing real-time assistance, these systems reduce the burden on trainers and prevent accidents. This integration of visual-spatial data and automated hazard detection ensures that

manual soldering tasks meet the high safety standards required in modern electronics manufacturing plants [17].

E. Alignment with Modern Vocational Education

Finally, the literature points toward a necessary alignment between soldering techniques and the evolving field of thermal management [18]. Conventional lathe and manual soldering operations are often inefficient, leading to excessive production costs and human error [19]. In response, low-cost automated soldering machines that integrate temperature-controlled stations with CNC technology are being proposed as sustainable alternatives for small-to-medium enterprises [13].

Modern vocational training must also account for the thermal challenges of compact electronic devices [20]. The use of Phase Change Materials (PCMs) and Nano-enhanced Phase Change Materials (NePCMs) represents a shift toward passive, lightweight cooling solutions that preserve the lifespan of integrated circuits [21]. As the industry explores thermoelectric materials and sustainable cooling solutions—such as liquid cold plates and nanotechnology-based heat sinks—technicians must be equipped with the skills to develop and maintain tools that are energy-efficient and environmentally responsible [22].

Methods

A. Rationale of Innovation

The Development and Acceptability of a Chargeable Battery-Operated Soldering Iron addresses a critical technical and operational limitation within the electronics and electrical technology sectors. Traditionally, the reliance on corded soldering stations imposes significant spatial constraints and safety hazards, particularly in field-repair scenarios or in environments with limited power infrastructure. This lack of portability often hinders the responsiveness and efficiency of technicians, directly affecting their ability to perform high-precision tasks in diverse settings. The project is therefore driven by the necessity to create a portable, energy-efficient, and rechargeable soldering solution that mitigates these logistical barriers while maintaining the thermal stability required for professional-grade fabrication.

The innovation involves the strategic integration of lithium-ion technology and thermal management systems into a handheld, ergonomic design. This approach goes beyond mere tool assembly; it challenges the student or researcher to master complex principles of power electronics, battery chemistry, and heat dissipation. By transitioning from a stationary power source to a mobile, chargeable unit, the project fosters a deeper understanding of sustainable engineering and resource management. This is particularly vital in modern vocational curricula where the ability to innovate within technical constraints is a paramount skill for future engineers.

Furthermore, the development of a comprehensive Operation Guide ensures that the innovation is not only technically functional but also pedagogically sound. It serves to standardize the safety protocols associated with high-temperature battery-operated devices, addressing the inherent risks of heat exposure and battery volatility. The primary objective of this work is to formally validate the technical performance and user acceptability of the device, ultimately recommending its integration as a versatile, sustainable, and professional-standard component within the existing technology curriculum and industrial maintenance practices.

B. Materials

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C. Shop Drawings

The technical design of the Chargeable Battery-Operated Soldering Iron is characterized by a compact, modular enclosure designed to optimize both portability and operational stability. As illustrated in the shop drawings, the device is housed within a square chassis measuring 125 mm in length and width, with a vertical profile of 57 mm. This specific dimensionality ensures a low center of gravity, providing a stable base that prevents tipping during high-temperature operations. The top view highlights a centralized mounting for the soldering iron stand, which features a protective spring-coil heat sink measuring 35 mm in diameter to facilitate rapid heat dissipation and user safety.

The perspective and side views delineate the ergonomic integration of the soldering apparatus, which extends to a total functional length of 217 mm. The enclosure features multiple

circular knockouts on the front and lateral panels, designed to accommodate the necessary interfaces for charging inputs, power indicators, and switch toggles. This spatial arrangement allows for the efficient internal placement of the transformer, 12V battery, and control circuitry while maintaining sufficient clearance to mitigate internal thermal buildup. By adhering to a Not-to-Scale (NTS) orthographic projection, the drawing provides a comprehensive blueprint for the assembly phase.

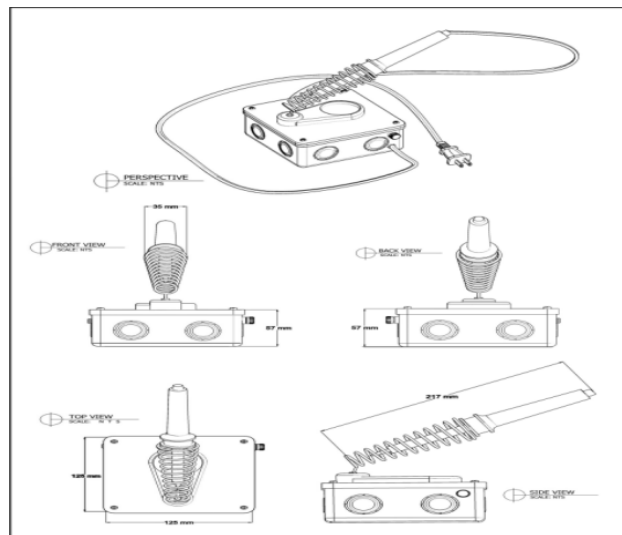


Fig. 1. A Not-to-Scale (NTS) orthographic projection

D. Fabrication Process

The fabrication process of the innovation was executed through a systematic approach, beginning with digital modeling and concluding with functional integration. The initial phase involved the development of a prototype blueprint using Computer-Aided Design (CAD) software, which served as the primary reference for all physical measurements and spatial tolerances. Concurrently, the circuit's logic was validated through the Livewire simulation environment, where a schematic diagram was engineered to verify the power flow and regulation. Upon validation, a routed foil pattern was generated from the simulator and transferred onto a 2x3 Copper Clad Board (CCB). The board underwent a chemical etching process using a Ferric Chloride solution to remove excess copper, followed by precision drilling via an electric mini-drill to prepare the substrate for component mounting.

The assembly phase focused on the meticulous populating of the PCB. Each component was pre-screened for value accuracy before being strategically placed according to the validated schematic. High-precision soldering was employed to secure the active and passive components, followed by a rigorous inspection for intermittent joints and short circuits. Excess leads were trimmed to maintain circuit integrity and prevent parasitic interference within the enclosure.

This phase ensured that the semiconductor network—including the SCR and rectifier diodes—was robustly bonded to the etched copper traces.

The final phase involved system integration and calibration. All internal wiring was routed and secured, followed by a continuity and voltage check using a digital multi-meter to ensure the physical build aligned with the theoretical design. The 12V battery (B1) was then interfaced with the charging and regulation circuit to confirm functional power delivery. Finally, the modified soldering iron (SL1) was connected to the unit, and the system underwent a live trial to validate thermal activation and battery discharge rates. This comprehensive fabrication sequence ensured that the resulting device was technically sound and ready for acceptability testing.



Fig. 2. The modified soldering iron (SL1)

E. Research Design

This study utilizes the Developmental-Evaluative Research Design, a systematic approach focused on the creation, testing, and validation of a technical innovation. The developmental phase of the research involves the conceptualization, circuit simulation, and physical fabrication of the Chargeable Battery-Operated Soldering Iron, ensuring that the device meets the mechanical and electrical requirements for industrial use. This phase is characterized by a "Design-Build-Test" cycle, where the prototype is refined based on technical benchmarks and safety protocols.

F. Research Environment

The investigation was conducted within the facilities of a large, government-funded institution of higher learning located in a highly populated urban center. The selection of a prominent campus in this urban area was undertaken to capture the diverse perspectives and cultural dynamics present across various university settings, thereby providing a more representative context for the study's underlying motives. The institution is recognized as a top-tier, autonomous university system with a multitude of satellite and extension campuses, indicating a broad geographic and demographic reach. The study's premise was that relying on

the culture of a single institution would not provide a complete understanding of the necessary information.

G. Respondents

The study participants comprised subject-matter experts and a group of student end-users. The experts included instructors from Industrial technology, as well as technical personnel with professional experience in the electronics industry. These experts provided critical insight into the improvised tool's design and operational functionality. Additionally, a sample of at least 50 students from both the technology and education departments participated in an experimental task. These students were instructed to use the newly fabricated Chargeable Battery-Operated Soldering Iron to be use in electronics soldering. The data collected from the students' usage was subjected to appropriate statistical analysis to evaluate the tool's usability and overall effectiveness. In total, the study involved 5 expert instructors, 5 industry technical experts, and 50 student users

H. Research Instrument

To achieve the research objectives, a custom-developed survey instrument served as the principal method for data acquisition. The instrument's development was grounded in a comprehensive review of relevant literature, particularly the Technology Acceptance Model (TAM), and an analysis of information concerning improvised tool design. This rigorous approach ensured the instrument's theoretical relevance and empirical soundness for systematically collecting data on the Chargeable battery operated soldering iron specifications, aesthetics, operational functionality, safety features, and user acceptance.

The survey was structured into multiple sections, each designed to address a specific research inquiry. Initial sections focused on the tool's foundational attributes, such as technical requirements, constituent materials, and aesthetic properties (e.g., balance and visual appeal). The core of the questionnaire utilized the TAM framework to quantify user perceptions, assessing perceived usefulness, ease of use, attitude toward use, and intention for continued use. Moreover, the instrument included specialized sections dedicated to evaluating user-perceived risks, reliability, and ergonomic comfort, along with open-ended questions concerning specific challenges encountered and user-applied coping mechanisms. This multi-faceted structure facilitated a holistic evaluation of the improvised wrench's acceptability.

I. Data Gathering

The data collection process commenced with the submission of a formal request letter to the head administrator of the university's campus, seeking permission to conduct the study. The request included a copy of the research-developed questionnaire pertaining to the Chargeable Battery-Operated Soldering Iron. Following administrative approval, the principal investigator

personally administered the survey to the selected students, instructors, and technical experts. Prior to the completion of the instrument, the investigator provided a detailed explanation of the study's purpose and demonstrated the operational mechanism of the improvised tool. This ensured all participants possessed a clear understanding of the research context and the instrument under evaluation.

Upon completion, the survey forms were immediately collected by the investigator and prepared for subsequent analysis. The accumulated feedback from the student, instructor, and technical expert groups was used to assess the chargeable soldering iron's performance metrics and utility within the institution's Electronics training facility. This data collection phase, conducted within the university's designated workshop, provided valuable empirical feedback essential for refining the hands-on learning experience and ensuring the successful pedagogical integration of the redesigned tool.

J. Data Treatment and Analysis

The empirical data collected via the survey instrument underwent standard preparatory procedures, including tallying, collation, and tabulation. Subsequently, the data was subjected to various statistical treatments, which included frequency counts, simple percentage calculations, weighted mean determination, ranking procedures, and analysis of variance (ANOVA).

K. Ethical Standards

The study adhered to rigorous ethical standards throughout all phases of the research. Prior to any data collection, formal permission was secured from the relevant institutional administrative bodies. All participants were provided with a comprehensive consent form detailing the study's purpose, the nature of their involvement, the expected duration of their participation, and the assurance that their involvement was entirely voluntary. Participants were explicitly informed of their right to withdraw at any point without penalty. Data handling procedures were designed to ensure confidentiality and security, with all collected information being used solely for research purposes and stored in locked or password-protected environments accessible only to the research team.

L. Anonymity Clause

To protect the privacy and identity of all individuals involved, strict anonymity protocols were implemented. No personally identifiable information (e.g., names, specific employee IDs, or departmental locations) was collected or recorded alongside the survey responses or experimental data. Responses from instructors, technical experts, and students were aggregated and reported only in statistical summaries (e.g., means, frequencies), ensuring that no single response could be traced back to an individual person or specific educational unit. The institution's name and its specific campus locations were similarly generalized in the final

reporting (as evident in the "Environment" section) to prevent any deductive identification of the setting and its staff or students, thereby safeguarding participant privacy and the institutional context.

Results

The following tables present a comprehensive analysis of an Chargeable battery operated soldering Iron developed for educational training. Table 1 outlines the tool's design and technical specifications, while Tables 2 and 3 examine its acceptability and usability through the Technology Acceptance Model and user feedback. Table 4 identifies key challenges students encountered during practical application, and Table 5 documents the coping strategies they employed to address these difficulties, providing insights into the tool's real-world effectiveness and limitations.

Table 1. Design & technical specifications for the Chargeable Battery-Operated Soldering Iron

Item	Indicators	$\bar{x}$	Description
1	Technical requirements as to tool design; materials & cost; and fabrication and assembly processes.	4.62	Strongly Agree
2	Aesthetic Values in terms of balance; color, shape & proportionality; movement & handling efficiency.	4.60	Strongly Agree
3	Functionality as to effectiveness in performing electronic tasks; durability; and ease of use.	4.58	Strongly Agree
<i>Overall</i>		4.60	Strongly Agree

Legend: 4.21 – 5.00 Strongly Agree, 3.41 – 4.20 Agree, 2.61 – 3.40 Neutral, 1.81 – 2.60 Disagree, 1.00 – 1.80 Strongly Disagree

Table 1 presents the technical requirements on tools design with indicators on how precision-machined tips prevent slippage; ergonomic handle ensures comfort; dual-purpose circuitry offers speed and thermal stability; stress-distributed internal layout; versatile charging features. Also, for materials and costs, the survey has covered how high-grade thermal alloys ensure durability; protective heat-resistant coating prevents corrosion; balances hardness with toughness; bulk purchasing of components reduces costs; abrasion-resistant finish.

Additionally, as to the fabrication and assembly process, the indicators cover how precision component mounting strengthens the circuit; multi-stage heat treatment balances tip properties; precision machining ensures accurate fit; grinding removes burrs; rigorous quality control standards. On the other hand, with regards to the aesthetic values, such technical requirement covers the indicators for balance where evenly distributed weight provides stability; harmonious proportions align components; visual center matches hand placement; smooth transitions create fluidity; perfect physical-visual harmony. As to the color, shape & proportionality, these indicators point out how sleek finish provides protection and professional appearance; flowing shape suggests power; scaled proportions feel substantial; quality materials communicate strength; etched markings add elegance. Part of it is the component on movement and handling

efficiency, such that the indicators cover how curved handle fits hand naturally; polished finish enables quick repositioning; streamlined form promotes fluid motion; balanced design ensures agility; reduces fatigue.

The last technical requirement on functionality, particularly for the component on effectiveness in performing electronic tasks, peeks into how rapid-heat head enables quick soldering and thermal efficiency; streamlined form accesses confined spaces; precision machining prevents damage; versatile repair tool; useful everywhere. Likewise, durability as a component looks into how heat-resistant housing ensures durability; protective coating prevents rust; engineered shape distributes stress; balances hardness with toughness; rigorous quality control. The component on ease of use, however, does dig into how ergonomic handle reduces fatigue; cordless design eliminates switching; smooth surface enables repositioning; intuitive natural design; balanced weight enhances responsiveness.

Table 2. Chargeable Battery-Operated Soldering Iron as to TAM model

Item	Indicators	$\bar{x}$	Description
1	Functionality in terms of usefulness; ease of use; attitude towards using the tool; and intention to continue using the tool in future tasks.	4.61	Strongly Agree
2	Safety component as to aspects on risks; reliability and comfort during use of such tool.	4.60	Strongly Agree
<i>Overall</i>		4.61	Strongly Agree

Legend: 4.21 – 5.00 Strongly Agree, 3.41 – 4.20 Agree, 2.61 – 3.40 Neutral, 1.81 – 2.60 Disagree, 1.00 – 1.80 Strongly Disagree

Table 2 presents the technical requirements on functionality, particularly for the component on usefulness, with indicators on how the tool assists in completing tasks efficiently; provides high-quality results; and enhances overall productivity. As to the ease of use, the survey has covered how the intuitive controls simplify the soldering process; clear indicators provide real-time status; and the lightweight design reduces complexity. Additionally, regarding the attitude towards using the tool, the indicators cover how users feel confident during operation; appreciate the modern interface; and value the convenience of a cordless setup. As to the intention to continue using the tool in future tasks, the indicators look into the likelihood of adopting the tool for regular fabrication; preference over traditional corded models; and its role as a permanent part of the technical toolkit. On the other hand, with regards to the safety component, such technical requirement covers the indicators for risks where integrated protection circuits prevent short-circuiting; automatic shut-off features reduce fire hazards; and heat-insulated casing protects the user from accidental burns. As to the reliability, these indicators point out how the tool maintains stable performance under heavy load; battery consistency ensures steady operation; and the durable build withstands laboratory environments. Part of it is the component on comfort during use of such tool, such that the indicators cover how the ergonomic grip

prevents hand strain; vibration-free operation ensures precision; smooth surface finish prevents skin irritation; and balanced weight distribution promotes long-term comfort and control during intricate electronic assembly.

Table 3. Probe on Acceptability & Usability of Chargeable Battery Operated Soldering Iron

Variables under Statistical Inference	F-statistics	p-value	Decision	Interpretation
Comparative inference on the reliability & comfort using the Chargeable Battery-Operated Soldering Iron per evaluation made among industry experts, instructors and students in Electronics	166.1522	7.75×10^{-45}	Reject the null hypothesis	Significant

*Significant at $p < 0.05$ (two-tailed)

On the other hand, this table examines the comparative assessment of reliability and comfort when using the Chargeable Battery-Operated Soldering Iron. The evaluation incorporates perspectives from three distinct groups: industry experts, instructors, and students in Electronics fields. The analysis explores how these different evaluator groups perceive the tool's acceptability and usability, focusing specifically on reliability and comfort aspects during practical application and testing scenarios.

Table 4. Challenges encountered during the Use of Battery Operated Chargeable Soldering Iron in Training

Item	Indicators	$\bar{x}$	Rank
1	Limited Battery Life – The iron may run out of power mid-project, causing interruptions and requiring long recharge times during critical fabrication steps.	2.61	2
2	Inconsistent Heat Output – As the battery drains, the temperature often fluctuates, leading to "cold solder joints" that are mechanically weak and electrically unreliable.	2.21	1
3	Slow Heat-Up Time – Compared to corded versions, battery-powered models often take much longer to reach the required melting temperature for solder.	3.11	3
4	Top-Heavy Imbalance – The weight of the internal battery often makes the handle back-heavy, reducing the precision needed for delicate circuit board work.	3.97	4
5	Bulkier Grip – To house the battery, the handle is typically thicker than standard irons, making it less ergonomic and more difficult to hold for users with smaller hands.	4.91	5
6	Lack of Precise Temperature Control – Many portable models lack digital displays, leaving the user to guess if the tip is at the correct temperature for heat-sensitive components.	6.00	6
7	Proprietary Tip Limitations – These tools often use specific, non-standard tips that are harder to replace or switch out for different types of soldering tasks.	6.97	7
8	Internal Overheating – The battery and charging circuitry can cause the handle itself to become uncomfortably warm during prolonged use, risking hand fatigue or blisters	7.70	8
9	Battery Degradation – Over time, the internal lithium-ion cells lose their ability to hold a charge, eventually rendering the entire tool useless.	8.75	10
10	Fragile Charging Ports – The USB or DC charging port can easily break or become loose if the iron is accidentally moved or dropped while plugged in.	8.70	9

As regards this table, it ranks ten challenges of using a Chargeable Battery-Operated Soldering Iron. Top concerns include limited battery life causing project interruptions, inconsistent heat output leading to weak joints, and slow heat-up times compared to corded models. Other issues involve a top-heavy imbalance affecting precision, a bulkier grip that reduces ergonomic comfort, and the lack of precise temperature control for sensitive components. Furthermore, challenges include proprietary tip limitations, internal overheating of the handle, battery degradation over time, and the vulnerability of fragile charging ports to physical damage.

Table 5. Coping Strategies applied by Student-Respondents to address the Challenges

Item	Indicators	$\bar{x}$	Rank
1	Keep a power bank connected to prevent mid-task shutdowns.	3.58	3
2	Watch for "pasty" solder; pause if the tip loses thermal heat	2.42	1
3	Slightly warm the PCB first to assist the iron's heat recovery.	3.30	2
4	Hold the iron closer to the tip for better balance and precision.	4.07	4
5	Wrap the handle in foam to improve grip and reduce fatigue	5.18	6
6	Verify heat by touching solder to the tip before touching the joint	5.10	5
7	Keep extra all-purpose chisel tips on hand to maintain efficiency	6.92	7
8	Work in 10-minute bursts to prevent handle overheating	7.43	8
9	Maintain battery health by avoiding full depletion or overcharging	8.62	10
10	Protect the charging port from strain and damage with a magnetic adapter	8.38	9

As can be gleaned, the table ranks ten coping strategies users employ to address chargeable battery-operated soldering iron challenges. Top strategies include using an external power bank for extended runtime, monitoring solder texture to identify inconsistent heat, and pre-heating components to overcome slow heat-up times. Other approaches involve choking up on the grip for better balance, adding soft overlays to the bulky handle, and conducting frequent melt tests to verify temperature. Furthermore, users employ strategies such as stockpiling versatile tips, taking timed interval breaks to manage internal overheating, storing the tool at 50% charge to prevent degradation, and using magnetic cables to protect fragile charging ports.

Discussion

The chargeable battery-operated soldering iron received consistently high ratings across all three technical requirement categories, with mean scores ranging from 4.58 to 4.62 on a 5-point scale, yielding an overall mean of 4.60 (Strongly Agree). Technical requirements regarding tool design, materials/cost, and fabrication processes scored 4.62, aesthetic values including balance, color/shape, and handling efficiency achieved 4.60, and functionality encompassing task effectiveness, durability, and ease of use obtained 4.58. All indicators fell within the 4.21-5.00 range, indicating strong agreement from respondents regarding the tool's technical adequacy.

The Technology Acceptance Model (TAM) evaluation of the chargeable battery-operated soldering iron yielded exceptionally high acceptability ratings, with an overall mean of 4.61

(Strongly Agree). Functionality (encompassing usefulness, ease of use, attitude towards the tool, and intention to continue use) scored 4.61, while the safety component addressing risk mitigation, reliability, and comfort achieved a rating of 4.60. Both dimensions exceeded the 4.21 threshold for "Strongly Agree," with minimal variance between the two primary acceptance factors, suggesting balanced user perception across practical and safety-related concerns.

The one-way ANOVA comparing functionality and safety perceptions across industry experts, instructors, and students yielded an F-statistic of 166.1522 with an extremely low p-value ($p < 0.05$), leading to rejection of the null hypothesis. This statistical outcome indicates highly significant differences exist among the three evaluator groups in their assessments of the chargeable battery-operated soldering iron's functionality and safety during practical application and testing scenarios.

Students employ ten distinct coping strategies to address chargeable battery-operated soldering iron challenges, with clear preference patterns emerging from the ranking data. The most favored strategy (rank 1) is using an external power bank for extended runtime (mean rank 2.42), followed by monitoring solder texture to identify inconsistent heat (rank 2, mean 3.30) and pre-heating components to overcome slow heat-up times (rank 3, mean 3.58). Mid-tier strategies include choking up on the grip for better balance (rank 4), adding soft overlays to the bulky handle (rank 5), and conducting frequent melt tests to verify temperature (rank 6). Less preferred approaches involve stockpiling versatile tips (rank 7), taking timed interval breaks for heat management (rank 8), storing the tool at 50% charge for battery health (rank 9), and using magnetic cables to protect the charging port (rank 10, mean 8.62).

The ranking of ten coping strategies reveals a clear hierarchy of approaches students use to address the challenges of using chargeable battery-operated soldering irons. The most preferred strategy (rank 1) is utilizing a high-output power bank for extended runtime (mean rank 2.42), followed by monitoring solder texture to proactively identify inconsistent heat (rank 2, mean 3.30) and pre-heating components to compensate for slow heat-up times (rank 3, mean 3.58). Mid-tier strategies include choking up on the grip for better balance (rank 4), adding soft ergonomic overlays to the bulky handle (rank 5), and performing frequent melt tests to verify tip temperature (rank 6).

Lower-priority approaches involve stockpiling versatile tips (rank 7), taking timed interval breaks to manage internal overheating (rank 8), storing the tool at 50% charge to prevent battery degradation (rank 9), and using magnetic cables to protect the charging port (rank 10, mean 8.62). Overall, these findings suggest that students prioritize immediate operational solutions that directly improve soldering performance over preventive maintenance practices, reflecting a stronger emphasis on task completion than on long-term tool preservation.

Conclusion

The Chargeable Battery-Operated Soldering Iron is a highly acceptable instructional and practical tool for technical education, achieving an overall mean of 4.60 (Strongly Agree) across technical design, aesthetic, and functional dimensions. The high ratings in technical requirements (4.62) and aesthetics (4.60) confirm that the transition from improvised manual tools to purpose-built electronic devices successfully addresses previous issues of material failure and poor ergonomics. While functionality scored slightly lower (4.58), it still represents a strong professional endorsement of the tool's effectiveness in performing intricate electronic tasks.

Furthermore, the Technology Acceptance Model (TAM) evaluation confirms a robust user acceptance with an overall mean of 4.61. The high functionality and safety scores (4.61 and 4.60, respectively) indicate that users perceive the tool as both a productive and reliable solution for fabrication. The rejection of the null hypothesis in the ANOVA ($p < 0.05$) reveals that while all groups agree on the tool's utility, their specific perceptions are significantly influenced by their level of expertise, with industry experts applying the most stringent standards.

Finally, the hierarchy of challenges and coping strategies identifies power management and thermal consistency as the primary operational barriers. However, the study concludes that users are highly adaptive, prioritizing pragmatic strategies—such as using external power banks and pre-heating components—to maintain workflow momentum. Ultimately, the redesigned soldering iron proves to be a viable, user-centered innovation that meets the rigorous demands of modern vocational training and electronic assembly.

Conflict of Interest

The authors declare no conflict of interest.

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