International Research Journal of Multidisciplinary Scope (IRJMS), 2025; 6(4):1624-1635

Original Article | ISSN (O): 2582-631X DOI: 10.47857/irjms.2025.v06i04.07267

Developing an Enhanced Foldable Bending Tool for Laboratory Tasks in the Civil Construction Technology Course

Mary Nena M Faulve*, Ludymae A Navarra, Julius Jay B Bayan, Ronelie G Melca, Loven A Corro

[1]Caraga State University- Cabadbaran Campus, Cabadbaran City, Agusan del Norte, Philippines. *Corresponding Author's Email: mmfaulve@csucc.edu.ph

Abstract

In construction education, particularly in Civil Construction Technology courses, students often face challenges when manually bending rebars, especially when forming precise 90° and 135° angles for lateral ties and stirrups due to inappropriate and custom-made or improvised bending tools. In order to close this gap, the research "Developing an Enhanced Bending Tool for Laboratory Tasks in the Civil Construction Technology Course" presents a dependable and simple-to-use tool for simplifying the bending of 10mm–12mm rebars. The tool features a fixed mechanical design comprising welded flat bars, various diameter rods (16mm, 20mm, and 25mm), a lever handle, a bolt-and-nut assembly, and a foldable base for easy mounting on wooden work surfaces. The tool was conceptualized, built, and refined using a developmental research approach at Caraga State University, Cabadbaran City. Structured surveys that included students and experts from the mechanical, metalworking, and construction sectors were used to evaluate the product's performance. The findings demonstrated compelling proof of its functionality in important areas, including its strength. Enhancements to the tool include a stronger bolt joint and a stopper mechanism that improves bend consistency and safety. According to the results, the improved bending tool is a helpful and successful alternative to conventional manual techniques, significantly increasing the accuracy, safety, and ease of rebar bending. With additional advancements and the possibility for increased production, this device has potential for applications in laboratories and wider use in fieldwork and construction education.

Keywords: Fixed Mounting, Foldable, Lateral Ties, Rebar Bending Tool, Stirrups.

Introduction

A bending tool is a forming machine, crucial for shaping metals in different and required forms (1). This tool is durable, fast, cost-effective, and valuable for bending reinforcement bars. Manual bending tools are lightweight and compact, allowing for easy portability. It can be transferred to different working sites in the laboratory area, helping to perform on-site bending operations. This can also offer creativity as it can be used to bend metals in different forms and sizes. Bending tools are also valuable for instruction delivery as an instructional material in laboratory classes; these tools help teachers and students bend bars to the required specifications. A manual bending tool is ideal for small-scale laboratory tasks, specifically for bending operations. It is easy to operate and does not require any training or skills. Civil Construction Technology (CCT) laboratories in the Philippines often rely on traditional, improvised bending tools for shaping steel rebars. These tools require a significant workforce, making it difficult for teachers and students to bend thicker or more rigid materials. The tool's static nature led to inconsistent bending angles. Furthermore, the tool's fixed location on a work table makes it difficult to move, necessitating several students to lift and relocate it. The extensive labor involved in this approach results in worker fatigue, lengthy procedures, and challenges in obtaining exact rebar angles and lengths. These restrictions emphasize the necessity for more effective and dependable bending techniques in the Philippine building sector (2). Additionally, during the bending process, the mechanical properties, geometrical, and internal structures of the steel rebars can be affected (3). If the steel rebars are improperly bent, it can cause corrosion and lead to cracks in the bend portion, which can damage the concrete structure, leading to building collapse. The high cost of professional-grade bending equipment limits its availability in various industries, including schools, small enterprises,

(Received 29th July 2025; Accepted 15th October 2025; Published 31st October 2025)

and manufacturing plants. This lack of access has far-reaching consequences, including jeopardizing safety, lowering labor quality, hurting local industry competitiveness, and impeding student learning. Due to the scarcity of high-quality equipment, schools have difficulty promoting skill development among students and teaching them the correct procedures. Insufficient equipment may cause students in the civil construction technology shops to create projects or items of inferior quality, which could raise safety issues. Addressing this issue requires a multi-pronged approach, including promoting knowledge sharing through training programs. The process of shaping stirrups involves various mechanisms, including feeding, bending, and cutting the rebar. Each mechanism requires precision and careful consideration to ensure synchronization with the others (4). Understanding these factors can help optimize the use of bending tools and improve the overall quality and efficiency of bending operations (5).

In this context, developing an improved foldable bending tool is a technical solution and an educational intervention. The tool supports skill acquisition aligned with Civil Construction Technology learning outcomes by enabling students to bend rebars more safely, accurately, and consistently. It minimizes risks of strain and injury, reduces material wastage, and provides students with a more reliable hands-on experience that mirrors industry practices. Thus, the innovation directly enhances competency-based learning while promoting laboratory safety (6). The project is conceptualized to help the Civil Construction Technology laboratory areas, including students and teachers, deal with the struggle of bending steel rebars that are inconvenient and time-consuming, and improve the angle and length precision of making stirrups and lateral ties.

Manual bending tools have been used for centuries. Hand tools for bending metal likely date back to the Industrial Revolution in the late 18th century, when metalworking techniques advanced. Manual bending tools like rebar benders became more common in the 20th century as construction and manufacturing processes became more standardized. Bending tools have evolved over centuries and were likely developed independently in various cultures. The earliest bending tools were simple implements used in metalworking, dating back to ancient civilizations such as the Egyptians and Romans. A metal bender is one of the tools used in manufacturing, especially in making engineering products by shaping the material into the required shape (7).

The manual rebar bending tool, as we know it today, started to emerge in the mid-20th century. However, manual bending methods for rebar have existed much longer, often utilizing basic tools like hammers and simple jigs. In more modern times, specific bending tools have been attributed to various inventors and companies during the Industrial Revolution and beyond, but comprehensive records are often lacking. Rebar benders allow accurate rebar bending to specific angles and shapes, ensuring the reinforcement meets design specifications. Compared to doing it by hand, manual and powered rebar benders greatly accelerate the bending process, cutting labor and time expenses on building projects. Furthermore, rebar benders minimize the risk of injury when bending rebar by hand because they are made to manage the required force safely (8). Precise bending improves the overall quality of the concrete structure, increasing its strength and safety (9). Rebar benders are indispensable for reinforcing concrete structures because they improve modern buildings' effectiveness, safety, and quality.

It is crucial to use methods that allow for easy and comfortable bending of work pieces while preserving the necessary angular accuracy during bench work. To encourage and aid in correct bending, especially when fabrication is time-sensitive, various equipment has been created and used, including rebar benders. To effectively produce the desired work pieces, a range of bending equipment is needed for industry production and laboratory tasks, such as bench work projects. These tools are convenient for the user and save time. It is crucial to investigate technologies that encourage correct bending while reducing labor-intensive and time-consuming tasks, given the impact of accuracy and productivity on bending operations (10).

Unlike conventional improvised bending tools that are heavy, static, and require multiple students to operate, the enhanced foldable bending tool is portable and user-friendly. This design allows individual students to independently perform bending operations, giving them more practice opportunities and greater control over the process. The safer and more efficient setup ensures that students can focus on mastering the correct bending techniques, directly supporting skill acquisition and improving learning outcomes in Civil Construction Technology courses.

Methodology

This study aimed to develop and assess the acceptability of an innovative product through a developmental approach. Unlike simple instructional development, developmental research entails a methodical approach to designing, producing, and testing instructional resources, programs, or goods to see whether they adhere to internal consistency and efficacy criteria. This method is essential to instructional technology, especially when it rigorously examines the development process and the result is carefully assessed (11).

Guided by the results of numerous tests to ascertain its practical effectiveness—particularly within the mechanical and civil construction—the study concentrated primarily on creating, developing, and improving technology design.

The researchers used a variety of tools to evaluate the performance of the experiment in order to collect the necessary data. To gather relevant data, the researchers employed a range of instruments to assess the performance of the developed Foldable Bending Tool. The evaluation covered key aspects of:

- Strength
- Overall Functionality

To ensure the reliability and effectiveness of the research instrument, the researchers submitted the survey questionnaire to the experts in metalworks and civil construction. They carefully reviewed and rated the instrument according to several criteria, including the clarity of directions and items, ensuring that the instructions and questions were clearly written and easy to understand. Additionally, vocabulary level, language structure, and conceptual clarity were used to confirm that the questions matched the knowledge and comprehension level of the respondents. The presentation and suitability of items were also validated to ensure logical organization, determine whether each question accurately represented the topic being studied, and measure the intended conditions, knowledge, and perceptions. Lastly, the objectivity, scale, and evaluation rating system were assessed to ensure that each item could be answered without bias and that the rating scale was appropriate for the data collection type. To further strengthen the validation process, the experts also evaluated the actual product developed by the researchers to determine whether the questions in the instrument aligned with the features and functions of the tool. The feedback helped refine and finalize the survey to ensure its relevance and accuracy.

The researchers applied statistical methods to gather data from the selected Caraga State University – Cabadbaran Campus (CSUCC) participants (students and experts/teachers). Specifically, frequency count, weighted mean, and standard deviation were used to determine the level of acceptability in the product's strength and functionality. The frequency count was used to identify how often each response option was selected, offering a clear view of response distribution. The weighted mean helped determine the overall acceptability level by calculating the average score based on the importance of each rating. Meanwhile, the standard deviation measured how consistent the responses were, showing whether participants had similar or varied assessments of the product.

Materials Contribution to Projects' Strength and Functionality

To guarantee the project's strength and reliability during bending, it is constructed using the following materials.

Table 1: Calculations and Dimensions

No	Description of Parts	Dimension (cm)	Types of Material/s
1	Lever Handle	100 x 2.4	Galvanized Iron Pipe
2	Pivot Bearing	1.9 x 3 x 2	Chrome Steel
3	Base Hinges	7.62 x 7.62	Stainless Steel

4	Pivot Rods	1.6 x 5 1.6 x 2 2 x 5 2 x 2 2.5 x 5 2.5 x 2	Steel
5	Pivot Rods Base	.6 x 5.08 x 14 .6 x 5.08 x 16.5 .6 x 5.08 x 20.5	Steel
6	Bolts and Nuts	1.9 x 1.2 x 2	Steel
7	Base	.6 x 90 x 86	Metal Mesh

The Table 1 shows the materials and dimensions utilized to guarantee the project's strength and dependability under bending. The materials chosen have a major impact on the device's strength and functionality (12). The lever handle, which is often used, is best suited for galvanized iron pipe because of its durability and corrosion resistance. The pivot bearing is made of chrome steel to provide wear resistance and seamless motion. Base hinges made of stainless steel are durable and strong in the face of stress. Steel parts, such as pivot rods, rod bases, bolts, and nuts, provide rigidity and structural support, which are necessary for operational stability. The basis is a lightweight yet strong foundation provided by the metal mesh. These materials guarantee that the gadget will continue to function properly, be robust, and be dependable even when subjected to mechanical strain.

Table 2: Bill of Material

Item No.	Qty	Unit	Description	Unit Cost (PHP)
1	1	Pc.	Steel Plate (3mm x 1200mm x 2400mm)	3800.00
2	1	Ft.	Flat Bar (1/4” x 2” x 11”)	495.00
3	1	Kgs.	E6013 Welding Electrodes (2.5)	100.00
4	1	Pc.	Bearing #630377	230.00
5	8	Pcs.	Bolt (19mmx 12mmx 1”)	200.00
6	36	Pcs.	Nut (19 mm x 12 mm) coarse thread	432.00
7	8	Pcs.	Washer helical spring lock 12mmØ	48.00
8	9	Pcs.	Cutting Disc (ǿ10.16 x 10.5)	200.00
9	3	Pairs	Hinges (3’’ x 3’’)	255.00
10	2	Pcs.	Grinding Disc	72.00
11	2	Ft.	Round Bar 16mmØ	94.00
12	2	Ft.	Round Bar 20mmØ	122.00
13	2	Ft.	Round Bar 25mmØ	268.00
14	2	set	8mm Bolt with nut and washer	52.00
15	4	Ft.	G. I. Pipe 1”	248.00
16	4	Pcs.	Lotus Quick Dry Enamel	140.00
17	1	Liter	Trend Metal Primer	225.00
18	1/4	Liter	Quick Dry Enamel Black	65.00
			Total	7046.00
			Labor Cost (40%)	2800.00
			Total Cost of the Project	Php 9,846.00

Table 2 presents the detailed bill of materials for the Foldable Manual Rebar Bending Tool, listing all components such as steel plates, rods, hinges, bearings, fasteners, and coatings used in the prototype. The total project cost is ₱9,846, including labor. The materials were selected to ensure strength, stability, and long-term usability of the tool in construction and laboratory applications.

Determining the Strength and Functionality

In order to evaluate the project's viability, the researchers ran a simulation using a series of steps:

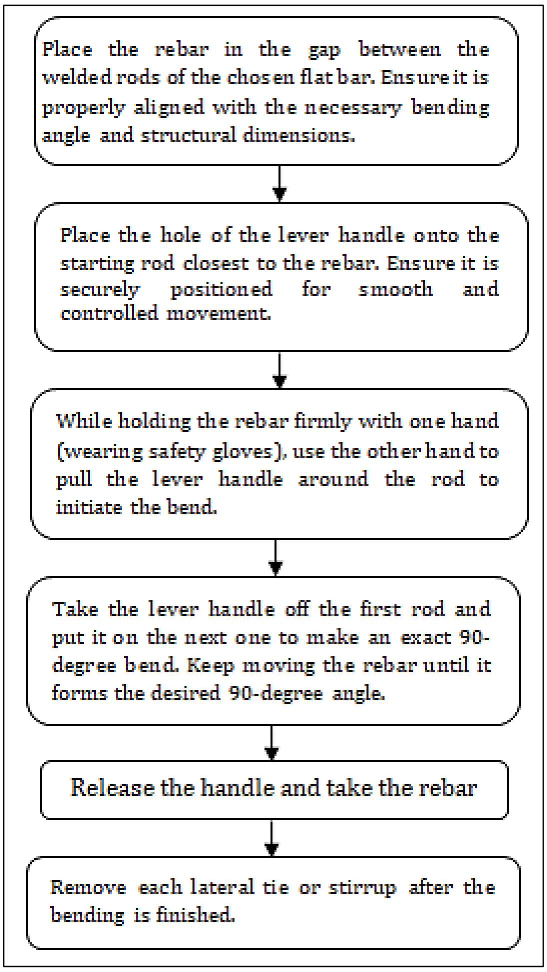

Figure 1: Steps in Testing the Project's Strength and Functionality

Figure 1 shows the series of steps followed in testing the tool's strength and functionality. It illustrates the bending procedure from positioning the rebar and securing the lever handle to achieving the desired 90° angle and removing the finished stirrups. The figure highlights the tool's ease of use, safety, and consistency during the bending operation.

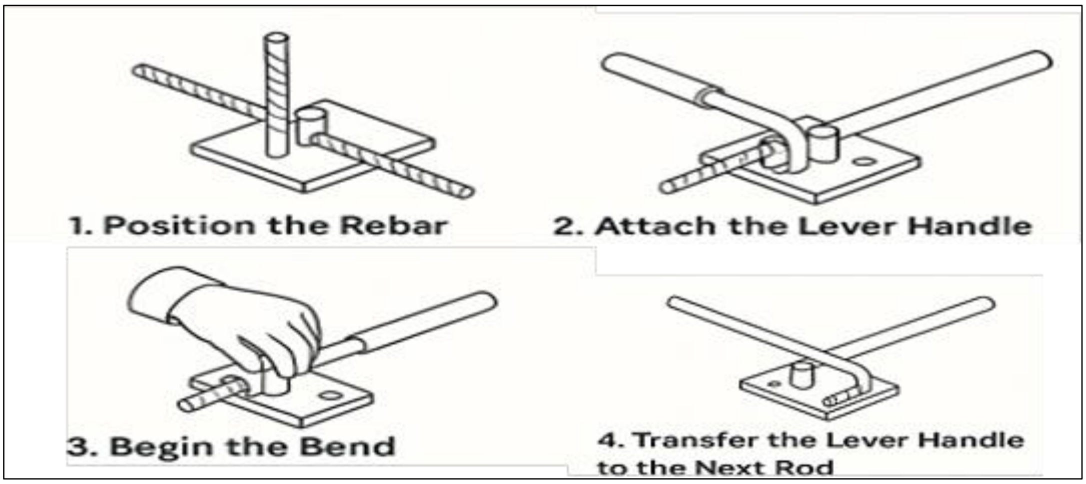

Figure 2: Proposed Bending Process

Figure 2 illustrates the step-by-step operation of the enhanced bending process, specifically bending 10mm and 12 mm rebars used in lateral ties and stirrups at 90° and 135° angles. The researchers used a methodical approach to assess the bending instrument's strength and functionality. Firstly, the rebar was placed between the welded rods on the chosen flat bar, ensuring it was properly aligned according to the necessary bend angle and structural size. The lever handle was then positioned on the starting rod closest to the rebar to facilitate regulated movement. The user started the bending operation by wrapping the lever handle around the rebar while holding it in place with one hand (while wearing safety gloves). The lever handle was taken off the first rod and moved to the next, continuing the movement until the desired angle was reached to produce a perfect 90-degree bend. The rebar was removed after the turn was finished, and the handle was let go. For every lateral tie or stirrup needed, this process was repeated 20 times.

Results

To support the simulation and demonstration, the researchers conducted surveys of the experts (mechanical technologists and construction workers) and students.

Table 3: Overall Tabulation of Responses in terms of the Project's Strength

Indicators	Mean			Verbal Interpretation
	Students	Experts	Grand Mean	
1. The product provides a strong lever handle that does not bend or warp during operation.	4.00	3.95	3.98	High Evidence
2. The product provides a solid rod and base that do not crack or change shape when bending rebars.	3.70	3.70	3.70	High Evidence
3. The product provides a secure bolt connection that does not loosen or break.	3.90	3.35	3.63	High Evidence
4. The product provides stability and strength when bending a 12mm rebar, which is the maximum intended size.	3.60	3.45	3.53	High Evidence
5. The product provides a stable base that prevents the tool from moving or tipping over during use.	3.90	3.60	3.75	High Evidence
6. The welded rods (16mm, 20mm, 25mm) stay firmly attached to the flat bar without breaking during bending.	3.90	3.35	3.63	High Evidence
7. The folding base locks securely and does not collapse or move when applying force.	3.60	3.60	3.6	High Evidence
8. The lever handle can repeatedly bend 10mm and 12mm rebars without bending or detaching.	4.00	3.90	3.95	High Evidence
9. The bolt-and-nut assembly securely fastens the components, even under the high pressure of rebar bending.	4.00	3.90	3.95	High Evidence
10. The entire frame remains stable and resists moving or shifting when mounted on a workbench during operation.	3.90	3.50	3.70	High Evidence
Total Grand Mean			3.74	High Evidence

Legend: 1.00-1.50: No Evidence, 1.51-2.50: Less Evidence, 2.51-3.50: Evidence, 3.51-4:00: High Evidence

Table 3 presents the overall tabulation of responses of both students and experts on the strength of the Foldable Manual Rebar Bending Tool. The grand mean of 3.74 indicates *High Evidence* in terms of material performance, indicating general agreement that the tool performs effectively under stress.

The highest ratings were for Item 8 (lever handle durability) and Item 9 (secure bolt-and-nut fastening), with means of 4.00 for students and

3.90 for experts in both cases. These results confirm that key mechanical components of the tool can withstand repeated, high-pressure use, making it reliable for daily operations in construction and training workshops. The lowest-rated item, Item 3 (secure bolt connection), had a grand mean of 3.63, slightly lower than the others but still within the *High Evidence* range. This indicates a possible area for design reinforcement, particularly for parts vulnerable to frequent movement and load.

The data strongly support the tool's structural integrity and resistance to deformation, vital for manual rebar bending in real-world settings. The results confirm that the tool's design meets occupational safety and performance standards, a finding consistent with emphasis on performance assurance through strength testing (13).

Moreover, tools used in educational environments must not only perform but also withstand repeated, instructional use, and the high ratings on repeatability (e.g., handle durability and locking mechanism) suggest the tool is ready for such contexts (14).

Table 4: Overall Tabulation of Responses in terms of the Project's Functionality

Functionality	Mean			Verbal Interpretation
	Students	Experts	Grand Mean	
1. The device can be securely mounted on a bench or working table during bending.	4.00	3.50	3.75	High Evidence
2. The lever handle operates smoothly and requires minimal effort to bend 10mm and 12mm rebars during use.	3.70	3.35	3.53	High Evidence
3. The bolt and nut assembly firmly holds the flat bar with welded rods (16mm, 20mm, and 25mm), ensuring stable and accurate bending of rebars.	3.90	3.50	3.70	High Evidence
4. The device can consistently bend 10mm to 12mm rebars without slipping or jamming.	3.60	3.60	3.60	High Evidence
5. The flat bar with welded rods (16mm, 20mm, and 25mm) enables effective bending of 10mm and 12mm rebars based on specific beam and column sizes.	3.90	3.35	3.63	High Evidence
6. The flat bar with welded rods can be easily attached to and detached from the base using a wrench tool.	3.90	3.45	3.68	High Evidence
7. The tool can bend rebars into stirrups and lateral ties with consistent shapes and angles of 90º and 135º.	3.60	3.50	3.55	High Evidence
8. The base is foldable for easy storage when not in use.	4.00	3.70	3.85	High Evidence
9. The welded rods are precisely aligned on the flat bar to ensure uniform bending angles for	4.00	3.90	3.95	High Evidence

multiple rebar pieces, helping maintain consistency in structural reinforcement.				
10. The device is designed for quick and secure tightening and loosening of bolts using a wrench, allowing efficient setup and adjustment during operation.	3.90	3.75	3.83	High Evidence
	Total Grand Mean		3.71	High Evidence

Legend: 1.00-1.50: No Evidence, 1.51-2.50: Less Evidence, 2.51-3.50: Evidence, 3.51-4:00: High Evidence

Table 4 presents the students' and experts' evaluations of the functionality of the Foldable Manual Rebar Bending Tool. The student-respondents gave strong and consistent ratings across all ten items, resulting in a grand mean of 3.71, interpreted as *High Evidence*. Notably, Items 1, 8, and 9 received a perfect mean of 4.00, indicating full agreement that the tool is easy to use and capable of producing accurate bends. While Items 4 and 7 had slightly lower means (3.60), these still fall within the *High Evidence* range, suggesting that students generally found the tool functional, reliable, and effective in meeting its intended purpose of forming lateral ties and stirrups.

The consistently high scores from student respondents indicated that the enhanced foldable manual rebar bending tool is effective, user-friendly, and capable of delivering functional performance (15-17), particularly in forming accurate 90° and 135° bends using 10mm–12mm rebars. Its design supports ease of use, crucial for educational settings and practical skills training. Tools like this have proven effective in developing hands-on construction skills in schools and training centers (18).

On the other hand, the slightly lower scores from expert respondents, particularly regarding precision and uniformity, highlight an opportunity for enhancement. Their feedback suggested that the absence of a built-in stopper or adjustable guide may lead to minor variations during repeated bending tasks. Such control features ensure consistency and operator efficiency in manual bending tools. A mechanical stopper could address this concern and increase repeatability in multiple bends (19). Furthermore, ergonomic and task-specific tool design is widely recognized as essential for reducing user fatigue and improving productivity in repetitive tasks (20, 21). This supports the implication that modifying the tool to better support repeated operations while maintaining its foldable, space-efficient form could enhance its appeal to technical instructors and field professionals. Overall, the findings from Table 4 reinforce that the tool performs well in terms of functionality but would benefit from minor design refinements to meet higher standards of precision and consistency, particularly in professional settings.

This study focused on creating a hand-operated tool that helps fabricate steel rebar components faster, easier, and more consistently for small-scale construction and educational settings. The tool was a manual, foldable bending device designed to bend 10 mm and 12 mm rebars, representing its maximum bending capacity, into lateral ties and stirrups essential for reinforced concrete columns and beams. The tool was designed to be simple, stable, and efficient, and it incorporates interchangeable flat bars with welded rods (16 mm, 20 mm, and 25 mm) to accommodate various tie sizes based on specific structural requirements. The research involved designing and fabricating a working prototype, followed by performance testing based on bending strength, including its accuracy and stability. Results showed that the tool maintained an accuracy tolerance of approximately ±3 mm per bend. It weighs around 25 kgs, making it lightweight and portable for laboratory classes. Durability tests confirmed that the prototype could withstand more than 20 repeated bends of 12 mm rebars without structural failure or deformation. Only steel-based components were considered in this prototype because of their availability and strength; alternative lightweight metals or composites were not tested. The foldable base withstood repeated opening and closing during these trials, indicating that the folding mechanism did not compromise durability within the scope of laboratory use.

The study also considered the practicality of the tool's structure, including its foldable base, welded bolt-to-base joint, nut fastening, and mountable design using nails to ensure it can be operated securely on a workbench or wooden platform. Unlike industrial bending machines, the tool operates entirely without electricity and is built to meet the needs of small-scale and hands-on applications. The prototype was tested by students and instructors in actual laboratory settings, confirming that it was safe, efficient, and effective for educational use. Similar research has shown that bolted and welded joints maintain integrity under bending loads and that joint design plays a critical role in tool performance and durability (22-24).

The study was limited to the manual bending of 10 mm and 12 mm steel rebars and did not include cutting mechanisms, motorized components, or automation features. It is not intended for rebars larger than 12 mm nor designed to replace commercial-grade bending machines. Its primary goal was to provide a cost-effective, easy-to-use alternative that simplifies the rebar bending, especially for forming lateral ties and stirrups used in structural reinforcement. Other applications not related to lateral ties and stirrups were beyond the scope of this study.

Discussion

The foldable manual rebar bending tool is designed to form lateral ties and stirrups using 10–12mm rebars. It features welded rods (16mm, 20mm, 25mm) attached to flat bars, a lever handle for bending, a foldable base for easy storage, and the ability to be securely mounted on wooden workbenches using nails. Selected experts and students conducted the final evaluation through a structured survey questionnaire. Overall, the tool was rated highly functional, with strong performance. The device earned a grand mean of 3.74, reflecting high evidence of structural strength. Evaluators highlighted the sturdy lever handle and reliable bolt-and-nut assembly, as seen in Table 3. However, a problem was noted where the nut detached from the base during bending, which could compromise tool stability. This issue was resolved by reinforcing the welded bolt-to-base connections and applying additional support measures to ensure consistent performance and maintain structural integrity during heavy use. These results are consistent with findings from previous research indicating that reinforced joints and ergonomic designs in manual rebar bending tools improve stability and accuracy. Similarly, precise alignment of bending components ensures consistent output, supporting the reliability observed in our tool. Ergonomic considerations also reduce user fatigue and improve performance in repeated tasks, which corresponds with the high functionality ratings from our evaluators.

With a grand mean of 3.71, which is shown in Table 4, the tool demonstrated high evidence of functionality. Respondents consistently praised its ability to bend 10mm–12mm rebars into accurate 90° and 135° angles. However, some evaluators pointed out that the absence of a built-in stopper made it difficult to achieve perfectly uniform bends, particularly when producing multiple stirrups or lateral ties. To improve this, a stopper feature was recommended and integrated to ensure precision and consistency in repeated bends. The evaluation results demonstrate the tool's technical strength and functionality and highlight its educational value. The key innovations of this tool are centered on its enhanced safety features (reinforced bolt assemblies and stopper mechanism), modularity through interchangeable welded rods, improved bending accuracy (±3 mm tolerance), and foldable portability, which collectively distinguish it from traditional improvised bending tools. By reducing reliance on improvised tools and excessive physical force, the foldable bending tool allows students to perform bending tasks more accurately and with less fatigue. This supports the development of precision skills that are directly aligned with Civil Construction Technology learning outcomes. In addition, the consistency of output angles improves students' confidence in their work, which enhances engagement in laboratory practice. In addition, the consistency of output angles improves students' confidence in their work, which enhances engagement in laboratory practice. By providing students with structured practice in rebar bending and structural detailing, the tool directly assists in honing their hands-on construction skills and reinforcing bar techniques, essential competencies in Civil Construction Technology courses. The foldable design further benefits teaching and learning since the device can be mounted, stored, and transported easily (25, 26).

The foldable design further benefits teaching and learning since the device can be mounted, stored, and transported easily, making it more accessible for group use in different laboratory settings. Enhanced safety features, such as the reinforced bolt-to-base connection and integrated stopper mechanism, minimize the risks of strain and injury during bending operations. This safer environment helps students focus on mastering procedures without being hindered by tool-related hazards. Compared with traditional improvised bending tools, the enhanced model ensures more uniform and professional-quality outputs and bridges academic learning with industry standards. The device contributes directly to skill acquisition in competency-based technical education by promoting safety, efficiency, and hands-on practice.

Conclusion

The study concludes that the Enhanced Foldable Manual Rebar Bending Tool successfully met its intended objectives as a versatile, durable, and instructional tool for educational and small-scale construction applications. The tool's features, such as its foldable base, welded interchangeable rods, manually operated lever handle, and secure bolt-and-nut assembly, address practical challenges in bending 10mm and 12mm rebars for lateral ties and stirrups. The consistent *High Evidence* ratings across all primary evaluation criteria, including design and construction, strength, functionality, and aesthetics, reflect the tool's strong performance and high level of acceptability among both student and expert users.

The results confirmed the tool's effectiveness in delivering accurate and repeatable bending operations, while maintaining ease of use, safety, and structural integrity. Student evaluations highlighted user-friendliness and instructional suitability, while expert feedback supported its functionality and practical relevance in field applications. These findings demonstrated that the tool can effectively serve as a standard piece of equipment in technical-vocational education workshops and small construction projects where precision, portability, and reliability are crucial.

Future studies could explore enhancing the tool's ergonomics for extended use, integrating digital or modular components such as angle indicators or sensors, and testing its performance with a broader range of rebar sizes. Researchers may also evaluate alternative materials to improve portability without compromising strength and assess long-term durability under real-world conditions. Comparisons with powered rebar bending machines could provide insights into efficiency, cost-effectiveness, and environmental impact. At the same time, field testing in vocational workshops or construction sites would help determine practical applicability and educational outcomes.

The evaluation feedback emphasized the value of user-centered design and continuous improvement. Suggestions regarding the reinforcement of bolt assemblies, alignment of welded rods, and adding a mechanical stopper for better control during bending highlight key opportunities for refinement. Addressing these areas will enhance the tool's durability, safety, and user satisfaction. Overall, the Foldable Manual Rebar Bending Tool exemplifies how practical design, informed by expert and user input, can lead to developing a functional, adaptable, and highly acceptable product suitable for both instructional and professional use. Beyond technical performance, the tool supports student learning outcomes by providing a safer, more reliable, and more accessible laboratory device that enhances skill acquisition and aligns with industry practices. In particular, the tool strengthens students' hands-on competencies by allowing repeated practice of reinforcing bar bending and structural detailing, making it an effective instructional aid for construction skills training. Based on the feedback from experts and students, the Foldable Manual Rebar Bending Tool would benefit from a few focused improvements to boost its durability, performance, and overall user satisfaction. These suggested changes include reinforcing the bolt-and-nut assembly to ensure it stays secure during repeated use, aligning the welded rods more precisely to achieve consistent bending angles, and adding a mechanical stopper or guide to make the tool safer and easier to control. Making these refinements will help ensure that the tool remains reliable, user-friendly, and effective whether used in a classroom setting or on an actual construction site. The tool's strong evaluation results suggest it has real commercial potential. The development team should consider affordable manufacturing options, appealing product branding, and effective distribution strategies to take it to the next level and prepare it for the market. Forming partnerships with vocational schools, training institutions, or hardware suppliers could help get the tool into the hands of more users. As long as the development process is centered around user needs, the tool can remain competitive and relevant in educational and professional construction settings.

Although this study focused on the manual design and basic mechanical performance of the Foldable Manual Rebar Bending Tool, future researchers are encouraged to explore further ways to improve its usability and adaptability. One area to consider is enhancing the tool's ergonomics to make it more comfortable for extended use and adding extra safety features to protect users during operation. It may also be valuable to explore integrating digital or modular components, for example, adding innovative features like digital angle indicators or built-in sensors that help ensure more precise bending results. Researchers might also consider incorporating adjustable pressure mechanisms, allowing the tool to handle a broader range of rebar sizes beyond the current 10mm and 12mm limitations. Another important area for future study is testing how the tool holds up under different working conditions, such as heavy use or harsh environments, to better understand its long-term durability and performance. In addition, trying out alternative materials, such as lightweight yet strong metals or composites, could help reduce the tool's weight and improve portability without sacrificing strength.

Further studies could assess how the tool affects user productivity and physical fatigue, mainly when used repeatedly in construction tasks. It would be helpful to better compare its efficiency, cost-effectiveness, and environmental impact with powered rebar bending machines to understand its advantages and limitations. Improving transportability by adding built-in storage or locking mechanisms for its detachable parts could also make the tool more practical for field use. Lastly, future studies should consider how the tool performs in actual training settings, such as workshops or on-site educational programs, to evaluate its impact on students' learning and skill development.

Abbreviations

CCT: Civil Construction Technology, CSUCC: Caraga State University: Cabadbaran Campus.

Acknowledgment

The researchers extend their heartfelt gratitude to the Caraga State University, Cabadbaran Campus community.

Author Contributions

Mary Nena M Faulve: contributed significantly to the study's topic, methodology, data collection, Ludymae A Navarra: responsible for the patent search, contributed to the project's design phase, Julius Jay B Bayan: prototype's design, conceptualization, fabrication, Ronelie G Melca: prototype's design, conceptualization, fabrication, Loven A Corro: validation of the instrument, conducted reliability testing.

Conflict of Interest

The authors of this work state that they have no conflict of interest regarding the publication of this study.

Declaration of Artificial Intelligence (AI) Assistance

The authors declare that generative artificial intelligence was used in the preparation of this manuscript. Specifically, ChatGPT was employed as an instrument in assisting the language refinement, formatting the Vancouver referencing style, and improving the clarity of claims. The authors thoroughly reviewed and validated the content to ensure originality and alignment with the study’s objectives. The final responsibility for the content rests completely with the authors. No artificial intelligence platforms were used to alter any data or even generate research data, analyses, and results.

Ethics Approval

No ethical clearance certificate applies to the present study. The authors of the submitted paper did not receive support from any organization.

Funding

No specific grant from a public, private, or non-profit organization was obtained for this.

References

1. Confesor JAB. An Experimental Study of an Improvised Portable Manual Rebar Bender. Indian J Sci Technol. 2021;14(27):2272–83.

2. Pang KK. Detail design of prototype portable cordless reinforcing steel combination cutter and bender [master's thesis]. Auckland: Auckland Univ Technol; 2019. https://hdl.handle.net/10292/12357
3. Wei J, Ren J, Zhou Z, Xie Y. Research on structural parameter optimization and springback compensation methods of a steel bar hoop bending machine. Appl Sci. 2023;13(17):9721.
4. Mezriche A, Mechaali C. Study of an automatic stirrup bending machine. Guelma (DZ): University of Guelma; 2023 Jun. http://dspace.univ-guelma.dz/jspui/handle/123456789/14703
5. Choayb MAM. Study of an automatic stirrup bending machine [bachelor's thesis]. Guelma: Univ Guelma; 2023. http://dspace.univ-guelma.dz/jspui/handle/123456789/14703
6. Pradhan BK, Wangmo D, Dendup J, Yeshi K, Drukpa K, Wangdi T. Design and fabrication of a portable manual roller bending machine. JNEC Thruel Rig Sar Toed. 2023;6(1). https://trst.jnec.edu.bt/index.php/thruelrigsartoed/article/view/16
7. Basharie SM. Metal-bending machine for lighter projects. Malays Res Innov Soc (MARI). 2023 Nov 8;4(4):136-43.
8. Deepu S, Vishnu RS, Harish MT, Bhavani RR. Experimental studies of force involved in manual rebar bending process. IOP Conf Ser Mater Sci Eng. 2018;310:012050.
9. Garad NS. Design and development of an automatic bending machine. Int J Eng Res Technol. 2020;9(6):977–83.
10. Tempel YA, Tempel OA, Surmyatova YV, Nekrasov RY. Digital technologies within the accuracy of processing low-rigid workpieces on CNC machines. In: Radionov AA, Gasiyarov VR, editors. Proceedings of the 9th International Conference on Industrial Engineering (ICIE 2023). Cham: Springer. 2023:708–17. https://link.springer.com/chapter/10.1007/978-3-031-38126-3_70
11. Ritchey RC. Developmental Research: The definition and Scope. Washington (DC): ERIC. 1994. https://files.eric.ed.gov/fulltext/ED373753.pdf
12. Feng Y, Yu H, Luo Z, Misra RDK, Xie G. The impact of process parameters on microstructure and mechanical properties of stainless steel/carbon steel clad rebar. Materials (Basel). 2019;12(18):2868.
13. Sasi DD, Rajendran V, Harish MT, Rao B. An experimental study of force involved in manual rebar bending process. IOP Conf Ser Mater Sci Eng. 2018;310(1):012050.
14. Ukuma S, Ochedikwu JO. Re-engineering vocational and technical education in Nigeria for greater quality service delivery in the 21st century for sustainable development. Acad J Interdiscip Stud. 2013;2(6):97.
15. Kırılmazkaya G, Dal SN. Effect of hands-on science activities on students' academic achievement and scientific attitude. Int J Educ Lit Stud. 2022;10(4):116–24. https://journals.aiac.org.au/index.php/IJELS/article/view/7427
16. Kotsis SV, Chung KC. Application of the "see one, do one, teach one" concept in surgical training. Plast Reconstr Surg. 2013;131(5):1194–201.
17. Love TS, Roper L, Monty M, Smith G. A national study examining safety factors and training associated with STEM education and CTE laboratory accidents. Saf Sci. 2023; 170:106980. https://www.sciencedirect.com/science/article/pii/S0925753522003976
18. Wei J, Ren J, Zhou Z, Xie Y. Research on structural parameter optimization and springback compensation methods of a steel bar hoop bending machine. Appl Sci 2023. 13(17):9721. https://doi.org/10.3390/app13179721
19. Jiang Y, Cheng X, Li H, Ren X, Li Y. Structural design of steel bar bending machine. Dali (CN): 7th International Conference on Mechanical Engineering, Materials and Automation Technology (MMEAT 2021); 2021 Jun 18–20. Bristol: IOP Publishing; 2021. https://doi.org/10.1088/1742-6596/1986/1/01209719.
20. Colim A, Faria C, Cunha J, Oliveira J, Sousa N, Rocha LA. Physical ergonomic improvement and safe design of an assembly workstation through collaborative robotics. Safety. 2021;7(1):14. doi:10.3390/safety7010014
21. Cicconi P, Trovato M, Donati L, Caputo AC. Defining the configuration of storage shelving in assembly workstations: an ergonomic tool for a parametric optimization. Ergonomics in Design. 2024. doi:10.54941/ahfe1004807
22. Xu Q, Zhu Y, Chen G, Xu D. Experimental Study on Flexural Performance of Screw Clamping and Welding Joint for Prestressed Concrete Square Piles. Buildings. 2025;15(3):480.
23. Fallahnezhad K, Steele A, Oskouei RH. Failure Mode Analysis of Aluminum Alloy 2024-T3 in Double-Lap Bolted Joints with Single and Double Fasteners; A Numerical and Experimental Study. Materials (Basel). 2015;8(6):3195-3209.
24. Kim D-K, Lee C-H. Experimental and analytical study of combined bolted-welded lap joints including high-strength steel. J Constr Steel Res. 2020; 170:106072.
25. Msimango SM, Mtshali TI, Khoza SD. Equipping civil technology teachers with hands-on skills and educational resources for effective teaching of practical lessons. Res Soc Sci Technol. 2024;9(2):341-358. doi:10.46303/ressat.2024.40
26. Patil KR, Ayer SK, Wu W. Characteristics of authentic construction learning experiences to enable accurate consideration of cost-effective alternatives. Buildings. 2025;15(14):24.

How to Cite: Faulve MNM, Navarra LA, Bayan JJB, Melca RG, Corro LA. Developing an Enhanced Foldable Bending Tool for Laboratory Tasks in the Civil Construction Technology Course. Int Res J Multidiscip Scope. 2025; 6(4):1624-1635. doi: 10.47857/irjms.2025.v06i04.07267