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Fostering Knowledge to Innovation: Enhancing Student Research Experience in Transforming Ideas into Project, Patent and Product

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Abstract—**This research study focuses on fostering a transformative journey from knowledge to innovation among students by enhancing their research experiences. The process involves converting initial conceptual ideas into tangible projects, which are subsequently developed into design patents, culminating in the creation of market-ready products. The study draws inspiration from the exploration of the critical radius of insulation, undertaken during the sixth semester of a mechanical engineering undergraduate program. This concept was practically applied to mitigate heat losses in household pressure cookers. Notably, a gap in the availability of such products in the Indian market was identified through extensive literature review, leading to the student's engagement in this project. Encouraged by their mentors, the students presented their innovation to the university innovation, incubation, and research center, successfully obtaining financial backing. This paper comprehensively recounts the entirety of the student's research journey. It commences with the translation of theoretical curriculum knowledge into actionable research ideas. The subsequent phases encompass various research methodologies, including theoretical analysis and simulation studies. The journey progresses with the execution of experimental approaches, effectively translating findings into design patents and, ultimately, tangible market-ready products. Overall, this research emphasizes the crucial role of research experiences in bridging the gap between theoretical learning and practical application. It underscores the significance of nurturing student's innovative capabilities within the structured curriculum, contributing to their holistic development as future contributors to academia and industry alike.**

***Keywords*—Idea; Energy; Patent; Research; Transformation.**

***JEET Category*—Research**

I. INTRODUCTION

Cooking food in the cooking pot causes energy loss as the temperature rises. Depending on the type of food and its quantity, the time required for cooking can go from 15 minutes to 1.5 hrs.

The need for saving energy and the planet has been a priority choice of all countries today. In India, most urban households use liquefied petroleum gas (LPG)/ Piped Natural Gas (PNG)
as their primary cooking fuel (Bhallamudi & Lingam, 2019). However, the price of cooking gas in India has increased significantly by about 50-60% in the last 10 years (Bharambe, 2013). This increase is mainly due to the gradual reduction of subsidies provided by the government, changes in global oil prices, and increased taxes. Additionally, the increasing demand for LPG both in India and globally has also contributed to the rise in price (Motwani & Patel, 2019). However, it is also noticed that, on average, about 30-40% of the heat energy can be lost from a cooking pot during the cooking process. Therefore, the increase in fuel price cannot be controlled by an individual, but saving energy while cooking may be overcome by providing a thermal insulation belt.

In this research, the idea was to examine the thermal insulation belt on the cooking pot primarily. The insulation belt can be wrapped on the outer side of the pot while cooking the food, which can cause a reduction in heat losses and saving of fuel. The cooking pot of 3 litres and glass wool as an insulating material was considered in the study. Theoretical and simulation results are conducted without and with insulation to evaluate savings in heat energy.

In the sub section, importance of fostering knowledge to innovation, approach of engineering design process, ideation of the concept, methodology of the research work, theoretical and simulation analysis, learning outcomes for the students and conclusion has been discussed.

II. IMPORTANCE OF FOSTERING KNOWLEDGE TO INNOVATION

Fostering knowledge to innovation is a cornerstone of enriching students' research experiences, guiding them through the seamless transition from conceptual ideas to tangible projects, patents, and market-ready products. Educational institutions play a pivotal role in creating an environment that values creativity and critical thinking, empowering students to amalgamate theoretical knowledge with practical application (Mishra et al., 2023). This transformative journey involves mentorship, interdisciplinary

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collaboration, and access to cutting-edge resources, providing students with the tools they need to thrive in the evolving landscape of technology.

Encouraging a mindset that embraces continuous improvement and entrepreneurial thinking ensures that students not only contribute to academic research but actively engage in the innovation ecosystem (Culture & Management, 2009) . This active participation translates their ideas into impactful projects, secures patents, and ultimately delivers market-ready products. Converting project ideas into innovation is a linchpin of engineering education, offering a multitude of benefits. Beyond conventional classroom learning, project-based activities provide students with real-world applications for theoretical knowledge, fostering a profound understanding of engineering principles.

This hands-on approach not only sharpens technical skills but also nurtures critical thinking and collaborative teamwork, positioning students as innovators. Successful innovation contributes not only to economic growth but also addresses pressing societal issues, propelling research and development endeavors and reinforcing a culture of continuous learning. Ultimately, converting project ideas into innovation serves as a catalyst for holistic student development, societal progress, and the advancement of technology and knowledge (Kumar & Parashar, 2012).

III. APPROACH OF ENGINEERING DESIGN PROCESS

Global science education faces challenges in addressing environmental shifts linked to sustainability. Stakeholders recognize the Education for Sustainable Development program amidst complex issues like climate change, depleting fossil fuels, and socio-environmental impacts on the economy (Abdurrahman et al., 2023). Consequently, imparting in students an awareness of the societal and environmental consequences of their work is imperative.

Engineering students should approach the engineering design process with a combination of creativity, methodical thinking, and a commitment to continuous improvement. Firstly, students should thoroughly understand the problem or challenge at hand, identifying key constraints and design criteria. Researching existing solutions and gaining insights from relevant literature can provide a foundation for informed decision-making. During the brainstorming and idea generation phase, students should embrace a diversity of perspectives and foster open communication to explore a range of innovative solutions. Moving to the conceptual design stage, it's essential to create rough sketches or models and critically evaluate each concept against the established criteria. As the design progresses to the detailed stage, precision in measurements, materials selection, and technical specifications becomes paramount. Building and testing prototypes offer invaluable insights, allowing students to refine and optimize their designs based on real-world performance. Embracing feedback, being open to iteration, and maintaining effective communication within a team are crucial aspects of the engineering design process. Ultimately, a holistic approach that blends technical acumen with creative problem-solving ensures that engineering students navigate the design process successfully and contribute meaningfully to innovative solutions (Tien, 2020). Fig. 1 illustrates about engineering design process.

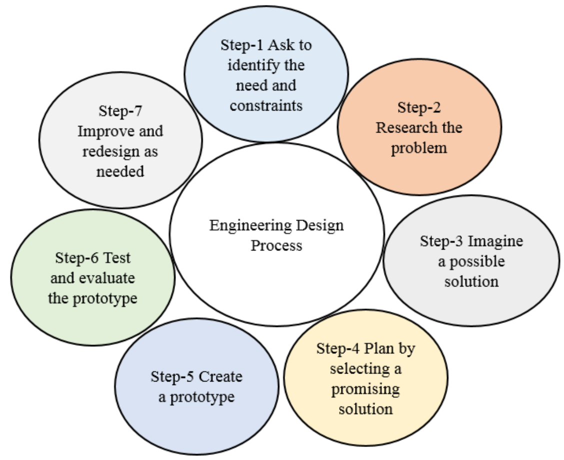

Fig.1 Engineering design process

IV. IDEATION OF THE CONCEPT

The idea for developing the flexible insulation belt was discovered after the subject heat and mass transfer was completed in the sixth semester. The concept of a critical radius of insulation gave more clarity about choosing the correct insulation thickness for reducing/increasing the heat transfer from cylindrical/spherical objects. Therefore, implementing the concept of the critical radius was prolonged to apply insulation on the home cooking pot. Furthermore, it was also recognized that cooking time at restaurants and hostel messes are very large for a particular food; using an insulation belt for this application will have significant potential to reduce losses and save energy.

V. METHODOLOGY OF THE RESEARCH WORK

First, a fall availability of such a product in the Indian market has been checked online, where no such products were found for the same process. Many research papers were reviewed from search engines like Google scholar, but very few research study was found. One of the experimentally study conducted by drissa et al. on metallic pressure cooker insulated with 15 cm thick kapok wool (density 50 kg/m^3). The investigation involved determining the time constant of the pressure cooker by analyzing the evolution of hot water-cooling temperature. Thermal losses were assessed through an energy balance on hot water exchanges with the environment. Results indicate low thermal losses, prolonged heat retention (approximately 60 hours), and significant energy savings in cooking (30% to 75%), emphasizing the pressure cooker's potential for efficient energy management in the restaurant sector (Ouedraogo et al., 2020).

Therefore, the idea in this primary study has been checked by conducting theoretical and simulation analysis. The cooking pot size was 3 litres so that sufficient surface area of the pot could be available for covering with insulation. While the outer wall of the cooking pot was assumed to be 150˚C for analysis purposes. The methodology of the research work step by step is shown in Fig. 2.

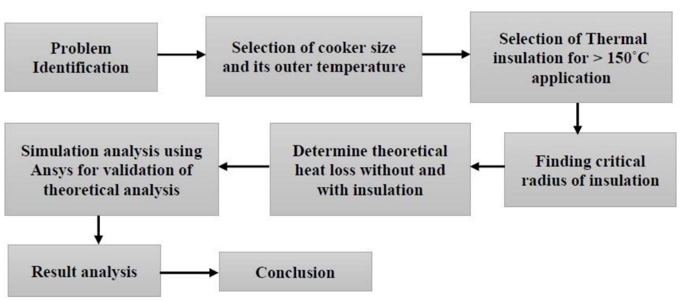

Fig. 2 Methodology of the research work

VI. DESIGN OF ENERGY EFFICIENT PRESSURE COOKER

The proposed design of the energy-efficient pressure cooker incorporates a flexible insulation belt along its outer periphery, aimed at mitigating heat losses when operating at elevated temperatures compared to its surroundings. Additionally, this design concept integrates an inbuilt blender attached to the cooker lid and a steam return pipe. It is noteworthy that the design for the energy-efficient pressure cooker has been granted a design patent, identified as patent number 366640-001. Fig. 3 illustrate the design of energy efficient pressure cooker.

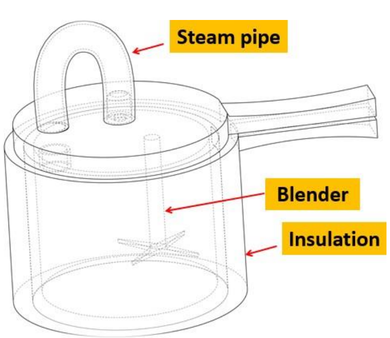

Fig. 3 Energy efficient pressure cooker

VII. THEORETICAL AND SIMULATION ANALYSIS

A. *Theoretical Analysis*

In heat transfer, a critical radius of insulation is defined as the radius at which the heat transfer is maximum and after which the addition of insulation causes a decrease in the heat transfer. The critical radius for cylindrical shape is given by (Cengel, 2003),

$$r_c = \frac{k}{h_o} \qquad (1)$$

Where, rc = Critical radius (m), K = Thermal conductivity of insulation (W/m˚C), ho = heat transfer coefficient (W/m^2˚C)

Heat transfer from the outer side of the cooking pot can be considered through the mode of convection and radiation. In this calculation, the radiation losses have been assumed negligible due to lower surface temperature. Therefore, the convection loss from the cooking pot outer surface to the surrounding can be given by (Cengel, 2003),

$$Q = h_o * A_s * (T_s - T_a) \qquad (2)$$

Where, Q = Rate of heat transfer (W), As = Surface area (m^2),
T_s = Surface temperature (˚C), T_a = ambient temperature (˚C). The following specifications mentioned in Table. I were considered for theoretical and simulation calculation.

TABLE I
SPECIFICATION CONSIDERED FOR CALCULATION

Parameters	Value
Cooker outer diameter (D)	0.142 m
Cooker height (H)	0.189 m
Glass wool conductivity (K)	0.04 W/m˚C
Outer surface temperature of cooking pot (T_s)	150 ˚C
Ambient temperature (Ta)	30 ˚C
Heat transfer coefficient (ho)	10 W/m^2˚C

Different insulation thicknesses were considered for calculating heat transfer using insulation, and the results are presented in a Table. II give below.

TABLE II
THEORETICAL HEAT LOSS

Thickness of insulation (cm)	Heat losses (W)
0	101.177

0.25	64.03
0.5	47.25
1.0	31.54
2	18.21

From the theoretical results as shown in the Table. II, it is noted that with increased insulation thickness, heat losses have been significantly reduced. However, in this case, the cooking pot radius is higher than the critical insulation radius, so putting any insulation thickness on the cooking pot heat losses will reduce only.

B. *Simulation Analysis*

In order to validate the theoretical heat losses, simulation analysis was conducted using the Ansys tool. In addition, thermal steady state structure analysis was considered for analysis. The procedure considered in the simulation analysis is mentioned below in the Fig. 4.

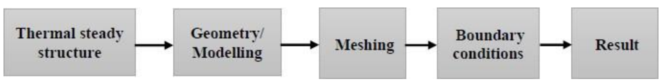

Fig. 4 Procedure of simulation analysis

Considering the specification mentioned in the Table. I, simulation analysis for computing heat losses with different radius of insulation was conducted using the ANSYS tool. The results of two samples of ANSYS are presented below for a cooking pot with no insulation in Fig. 5 and 0.5 cm insulation in Fig. 6. The complete simulation results of heat losses without and with different insulation thicknesses is shown in Table. III.

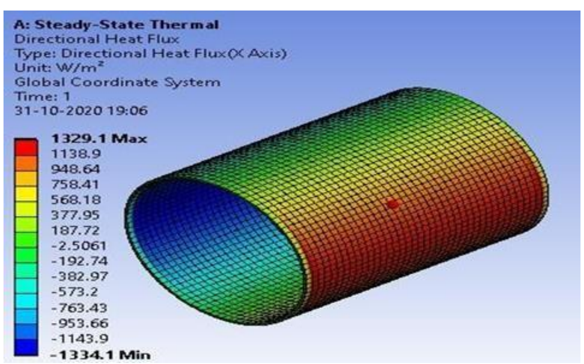

Fig. 5 Cooking pot with no insulation

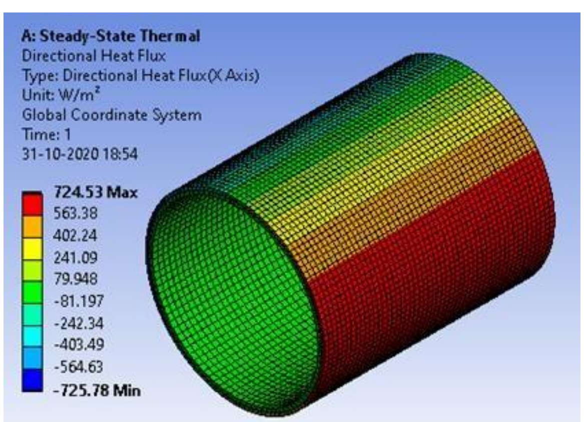

Fig. 6 Cooking pot with 0.5 cm insulation

TABLE III
SIMULATION HEAT LOSS

Thickness of insulation (cm)	Heat losses (W)
0	111.99
0.25	61.077
0.5	44.136
1.0	30.56
2	17.78

From the simulation results as shown in the Table. III, it is noted that with increased insulation thickness, heat losses have been significantly reduced.

Therefore, it can be noted that theoretical and simulation results shows good match.

VIII. LEARNING OUTCOMES FOR THE STUDENTS

There are total of 10 learning outcomes has been found out from this transformative journey, are listed below:

1. Research Ideation and Conceptualization:

Students demonstrate the ability to translate theoretical curriculum knowledge into actionable and innovative research ideas.

2. Application of Theoretical Knowledge:

Learners have apply theoretical analysis and simulation studies to validate and enhance their research concepts, showcasing a practical understanding of academic principles.

3. Experimental Design and Execution:

Students developed proficiency in designing and executing experimental approaches, gaining hands-on experience in translating theoretical findings into practical solutions.

4. Innovation and Patent Development:

Participants have engage in the development of design patents, illustrating their capacity to transform conceptual ideas into tangible intellectual property.

5. Market-Ready Product Creation:

Learners have successfully demonstrate the capability to progress from initial conceptualization through design and experimentation to the creation of market-ready products.

6. Identification of Market Gaps:

Students showcased critical thinking skills by identifying gaps in the market through extensive literature review and proposing innovative solutions to address these gaps.

7. Communication and Presentation Skills:

Participants have enhance their communication and presentation skills by effectively conveying their research journey, findings, and innovations to peers.

8. Financial Proposal Development:

Learners developed competence in creating compelling financial proposals, as demonstrated by their successful acquisition of financial backing for their innovative project.

9. Holistic Understanding of Research Process:

Students have gain a holistic understanding of the research process, encompassing ideation, theoretical analysis, experimentation, patent development, and the creation of market-ready products.

10. Contribution to Academia and Industry:

The study aims to foster students' holistic development as future contributors to academia and industry, emphasizing the integration of innovative capabilities within the structured curriculum.

IX. CONCLUSION

In conclusion, this research study has showcased the significant impact of fostering a journey from knowledge to innovation among students through enhanced research experiences. By converting theoretical ideas into practical projects, design patents, and market-ready products, students were able to bridge the gap between academic learning and real-world application. The study focus on insulation as a means to reduce heat losses in cooking pots illustrates the potential for energy savings and improved cooking efficiency. The research demonstrates that thermal insulation can lead to substantial reductions in heat losses, with varying degrees of improvement depending on insulation thickness. While the study acknowledges the importance of proper insulation thickness selection due to considerations of weight and cost, it highlights the positive impacts on energy conservation from both LPG and PNG cylinders during cooking. The potential adaptability of the insulation belt to different pot sizes further enhances its practicality. However, the study recognizes that these findings are based on theoretical and simulation analyses, and further experimentation is essential to validate and refine the concept under practical conditions where cooking pot temperatures may fluctuate. Despite being an initial exploration, this research underscores the potential of integrating innovative experiences into structured curricula, fostering holistic development among students and preparing them for contributions to academia and industry.

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