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Bridging Theory to Practice: Utilizing Revised Bloom's Taxonomy in Entrepreneurship and Innovation Education for Engineers

Ahmed Abdou[1]

[1] PhD in Systems Engineering and Psychoanalysis, Palestine Ahliya University (Palestine)

✉ a.abdou@paluniv.edu.ps

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Abstract:

This study aimed to explore the feasibility of applying the Revised Bloom's Taxonomy in teaching entrepreneurship and innovation courses to students, in order to enhance critical thinking, creativity, and problem-solving skills. The research adopted an analytical case study methodology, where the Revised Bloom's Taxonomy was applied to a sample of 80 engineering students enrolled in an entrepreneurship course at Palestine Ahliya University. These students participated in the GSCACS project in partnership with the City University of New York, engaging in virtual exchanges focused on Sustainable Development Goals (Goals 6 and 10). The course activities and assessments were designed according to the six levels of the Taxonomy (Remembering, Understanding, Applying, Analyzing, Evaluating, Creating) to ensure the development of cognitive skills. The results showed that the students' practical projects, which focused on drinking water and healthcare issues, effectively embodied the application of all Taxonomy levels, progressing from remembering information to creating innovative technological solutions. The study recommends expanding the use of this approach in engineering departments, training faculty on its integration, and adopting assessment criteria focused on higher-order skills. The originality of this study lies in providing a documented practical framework for applying the Revised Bloom's Taxonomy in an Arabic context for teaching entrepreneurship to engineers, focusing on developing innovative solutions for sustainable development challenges.

Keywords: *Revised Bloom's Taxonomy; Creativity; Critical Thinking; Problem-Solving Skills; Entrepreneurship and Innovation.*

ربط النظرية بالممارسة: استخدام تصنيف بلوم المنقح في تعليم ريادة الأعمال والابتكار للمهندسين

أحمد عبدو [1]

[1] دكتوراة في هندسة النظم وتحليل الإشارات والصور، جامعة فلسطين الأهلية (فلسطين)

a.abdou@paluniv.edu.ps

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ملخص:

هدفت الدراسة إلى استكشاف إمكانية تطبيق تصنيف بلوم المنقح في تدريس مقررات ريادة الأعمال والابتكار للطلبة، وذلك لتعزيز مهارات التفكير النقدي والإبداعي وحل المشكلات. اتبعت الدراسة منهج دراسة حالة تحليلية، حيث تم تطبيق تصنيف بلوم المنقح على عينة مكونة من (80) طالباً من طلبة الهندسة الملتحقين بمساق ريادة الأعمال في جامعة فلسطين الأهلية، إذ شارك هؤلاء الطلاب ضمن مشروع (GSCACS) بالشراكة مع جامعة مدينة نيويورك، والمبادرات الافتراضية حول أهداف التنمية المستدامة (الأهداف 6 و10). تم تصميم أنشطة المقرر وتقييماته وفقاً لمستويات التصنيف الستة (التذكر، الفهم، التطبيق، التحليل، التقييم، الإبداع) لضمان تطور المهارات المعرفية. أظهرت النتائج أن المشاريع العملية للطلبة، والتي ركّزت على قضايا مياه الشرب والرعاية الصحية، تُجسّد تطبيقاً فعالاً لجميع مستويات التصنيف، حيث تدرّجت من تذكر المعلومات إلى إنشاء حلول تقنية مبتكرة. أوصت الدراسة بتوسيع استخدام هذا الأسلوب في أقسام الهندسة، وتدريب الأساتذة على دمجه، واعتماد معايير تقييم تركز على المهارات العليا. تتمثّل أصالة هذه الدراسة في تقديم إطار عملي موثق لتطبيق تصنيف بلوم المنقح في سياق عربي لتعليم ريادة الأعمال للهندسة، مع التركيز على إنتاج حلول مبتكرة لقضايا التنمية المستدامة.

الكلمات المفتاحية: *تصنيف بلوم المنقح؛ الإبداع؛ التفكير النقدي؛ مهارات حل المشكلات؛ ريادة الأعمال والابتكار.*

1. Introduction

Entrepreneurship and innovation represent pivotal aspects of modern engineering education, reflecting the dynamic demands of industries worldwide. In today's landscape, engineering graduates are not only expected to possess technical proficiency but also to demonstrate adeptness in problem-solving, creativity, and critical thinking. To meet these evolving demands, educators are continuously exploring effective pedagogical approaches that facilitate holistic skill development among engineering students (Yin, 2018).

One such approach involves the utilization of educational frameworks, among which Bloom's Taxonomy stands out as a prominent example. Initially conceptualized by Benjamin Bloom and his collaborators in 1956, Bloom's Taxonomy provided a structured classification of educational objectives primarily within the cognitive domain (Bloom, 1956). However, it wasn't until the taxonomy's revision in 2000-2001 those contemporary educational practices and the significance of higher-order thinking skills were comprehensively integrated into its framework (Anderson, 2001).

This paper aims to explore the nuanced application of Revised Bloom's Taxonomy within the context of Entrepreneurship and Innovation education for engineers. By leveraging the taxonomy's hierarchical structure, educators can tailor course objectives, activities, and assessments to align with the cognitive complexity levels outlined in the revised taxonomy. This alignment facilitates the creation of a more nuanced and engaging learning environment catering to diverse learning styles while fostering deeper understanding and retention of concepts.

It is crucial to acknowledge the collaborative efforts of Benjamin Bloom and David Krathwohl in the development and refinement of Bloom's Taxonomy. While Bloom is often credited as the primary author, Krathwohl's contributions, particularly in the 2001 revisions, played a pivotal role in modernizing the taxonomy to meet the evolving needs of education (Anderson & Krathwohl, 2001) (Krathwohl, 2001).

Through an in-depth exploration of practical strategies and case studies, this paper seeks to elucidate how Revised Bloom's Taxonomy can be effectively integrated into Entrepreneurship and Innovation courses for engineers. By emphasizing critical thinking, creativity, and problem-solving skills, this pedagogical approach aims to empower engineering students with the competencies necessary for success in the dynamic landscape of entrepreneurship and innovation (DeTienne, 2004).

Additionally, Table 1 compares Bloom's Taxonomy (1956) with Anderson and Krathwohl's Revised Taxonomy (2001), (Fayolle, 2006) (Neck, 2011) highlighting the evolution and expansion of cognitive skill categories. This comparison underscores the advancements in educational theory, providing educators with a more comprehensive framework for designing instruction and assessing student learning outcomes.

Furthermore, the paper discusses the importance of educational outcomes in engineering programs, ranging from overarching Program Educational Outcomes (PEOs) to specific Student Outcomes. Aligned with accreditation standards such as those set by Accreditation Board for Engineering and Technology (ABET), these outcomes ensure that engineering programs effectively prepare graduates for their professional careers while fulfilling the broader educational objectives of the institution (Morris et al., 2009).

Table1: Comparison of Bloom's Taxonomy (1956) and Anderson and Krathwohl's Revised Taxonomy (2001)

Bloom's Taxonomy (1956)	Anderson and Krathwohl's Revised Taxonomy (2001)
1. **Knowledge**: Remembering previously learned material.	1. **Remembering**: Recognizing or recalling knowledge from memory. Involves retrieving facts, definitions, or previously learned information.
2. **Comprehension**: Grasping or constructing meaning from material.	2. **Understanding**: Constructing meaning from various types of messages or activities, such as interpreting, summarizing, or explaining.
3. **Application**: Using learned material in new and concrete situations.	3. **Applying**: Carrying out or using a procedure through execution or implementation. Involves applying learned material in products like models or presentations.
4. **Analysis**: Breaking down material into its components to understand its structure.	4. **Analyzing**: Breaking materials or concepts into parts and understanding their relationships or overall structure. Involves differentiating, organizing, and attributing components.
5. **Synthesis**: Putting parts together to form a coherent whole.	5. **Evaluating**: Making judgments based on criteria and standards through checking and critiquing. Involves creating critiques, recommendations, or reports.
6. **Evaluation**: Judging the value of material for a given purpose.	6. **Creating**: Putting elements together to form a functional whole or reorganizing them into new patterns. Involves generating, planning, or producing new forms or products.

2. Methodology:

Entrepreneurship and innovation education for engineers is the best way to equip students for the evolving and rapidly changing landscape of the modern workplace (Hisrich, 2017). To equip engineering students with knowledge, skills, and a mindset to excel as innovative entrepreneurs and problem solvers, a systematic and integrated approach to curriculum design and pedagogy was adopted. This method was based on the implementation of effective entrepreneurship and innovation education based on the integration of Revised Bloom's Taxonomy, a framework for developing cognitive development and higher-order thinking skills.

The method consisted of a series of interconnected steps that would guide the design, delivery, and evaluation of the entrepreneurship and innovation education program to meet the needs of engineering students (Filion, 1999). This commenced with a needs analysis and curriculum development stage, in which specific learning outcomes, competencies, and pedagogical approaches required to build an entrepreneurial mindset and skillset among students were identified. This was followed by the selection of appropriate pedagogical approaches, such as experiential learning and project-based learning, to engage students in active and inquiry-based learning experiences.

At the forefront of this strategy was the integration of Revised Bloom's Taxonomy. This provided a structure for scaffolding learning activities and assessments into different levels of cognitive complexity. The course learning objectives, learning activities, and assessments were aligned onto the levels of the Revised Bloom's Taxonomy, facilitating sequenced learning experiences that challenged students to move from rote memorization to the higher-order thinking skills of critical thinking, problem-solving, and creativity.

The implementation and delivery phase centered on creating a learner-centered environment where collaboration, reflection, and application of entrepreneurial concepts to real life were fostered. A blended learning approach that combined face-to-face learning with online material and interactive technology was used. This provided students with different learning opportunities and built their entrepreneurial orientation and ability (Solomon, 2002). Continuous assessment and evaluation ensured students met pre-established learning objectives and were adequately prepared to manage entrepreneurial ecosystem requirements (Valerio et al., 2014; Kuratko, 2005).

2.1 Study Sample

The sample included 80 male and female students of engineering pursuing an entrepreneurship course at Palestine Ahliya University (PAU). The students participated as part of the Global Scholars Achieving Career Success (GSCACS) project, in association with the City University of New York (CUNY). The GSCACS project involved virtual exchanges on UN Sustainable Development Goals (SDGs), SDGs 6 and 10 here. The sample engaged in group work and interactive exercises with CUNY and other MENA institution peers.

2.2 Study Instrument

The primary tools for the findings of the study were the course activities guided and tests formulated according to the Revised Bloom's Taxonomy framework. These included:

- Project-based learning modules on SDGs 6 and 10.
- Business Model (BM) and Business Model Canvas (BMC) exercises for idea development and conducting feasibility studies.
- Competitor analysis assignments.
- Peer review and feedback sessions (e.g., presentations to marketing students at other institutions).
- Preparation and attendance at a student conference to present final projects.

2.3 Implementation Procedures

- Needs Assessment & Curriculum Design: A curriculum was created with theoretical concepts and practical applications, with specific alignment with Revised Bloom's Taxonomy objectives.
- Pedagogical Approach Selection: Experiential and project-based learning approaches were chosen. The GSCACS framework provided a blueprint for collaborative, real-world problem-solving aligned with SDGs.
- Learning Resource Development & Integration: Relevant case studies, examples, and SDG-specific content were chosen. The Revised Bloom's Taxonomy was integrated by aligning course objectives, learning activities (like the SDG projects, BMC development), and assessments (like the final conference presentation) to its cognitive levels (Remembering to Creating).
- Implementation & Delivery: Blended delivery was employed in implementing the curriculum. Students participated in English language workshops, created SDG projects, and engaged in virtual exchanges. A learner-centered environment was created.
- Assessment & Evaluation: Assessment of students' learning was done by employing several formative and summative strategies. Authentic assessment included developing business models, feasibility studies, competitor analysis, and delivering the final project presentations at the student conference.
- Continuous Improvement & Reflection: The process involved the refining of ideas based on feedback and preparation for the final showcase.

This methodology served as a roadmap for creating and delivering an entrepreneurship and innovation education program from theory to practice, utilizing Revised Bloom's Taxonomy to guide cognitive development.

3. Results and Discussion:

Through the discussion of the revised Bloom's taxonomy model, the complete parts were applied as follows:

A. Remembering

During the review of course objectives, students revisited the core principles of entrepreneurship, including identifying market opportunities, understanding customer needs, and developing innovative solutions. They also recalled the importance of financial viability, scalability, and sustainability in entrepreneurial ventures. Furthermore, they reflected on the role of teamwork, creativity, and adaptability in the entrepreneurial process. Indeed,

B. Understanding:

In explaining each stage of creating a startup, students delved into specific methodologies and tools used in the entrepreneurial journey. They explored techniques for ideation, such as brainstorming sessions, market research, and customer interviews. Additionally, they discussed strategies for product development, prototyping, and testing. Understanding the legal and regulatory requirements for starting a business, as well as the significance of building a strong brand and customer base, was emphasized.

C. Applying

The application phase involved hands-on exercises where students translated theoretical concepts into practical actions. They worked collaboratively to develop business models, draft business plans, and create prototypes of their products or services. Through iterative cycles of feedback and refinement, they honed their ideas to meet the needs of their target market. Utilizing lean startup principles, they adopted an agile approach to product development, iterating quickly based on customer feedback.

D. Analyzing

During the analysis stage, students conducted in-depth research to assess market trends, identify competitors, and evaluate potential risks and opportunities. They utilized various analytical tools and frameworks, such as SWOT analysis, Porter's Five Forces, and PESTLE analysis, to gain insights into the competitive landscape. By critically evaluating their business ideas and value propositions, they were able to identify key differentiators and formulate effective strategies for market entry and growth.

E. Evaluating

In the evaluation phase, students engaged in real-world interactions with industry professionals, investors, and potential customers. They pitched their ideas and MVPs to local and American companies, seeking feedback and validation. Through networking events, pitch competitions, and mentorship programs, they leveraged external expertise to refine their business models and validate their assumptions. By soliciting feedback from diverse stakeholders, they gained valuable insights into market demand, pricing strategies, and scalability.

F. Creating

The culmination of the entrepreneurship course was a student conference where participants showcased their final projects and outcomes. In addition to presenting their business ideas and MVPs, students prepared comprehensive reports and presentations documenting their entrepreneurial journey. They highlighted key learnings, challenges encountered, and achievements attained throughout the course. The conference provided a platform for students to celebrate their accomplishments and receive recognition for their innovative endeavors. Furthermore, it served as an opportunity for networking, collaboration, and future partnerships among aspiring entrepreneurs and industry professionals.

By emphasizing hands-on learning experiences and interactive exercises, educators fostered an entrepreneurial mindset among students, instilling in them the confidence and resilience needed to pursue innovative ventures. Through collaborative projects, industry engagements, and mentorship opportunities, students were able to leverage their skills and knowledge to tackle real-world challenges and create tangible impact.

Overall, the utilization of Revised Bloom’s Taxonomy in entrepreneurship and innovation education has empowered engineering students to become proactive agents of change and innovation in the global economy. By bridging the gap between theory and practice, this approach equips students with the tools, mindset, and capabilities necessary to thrive in today's dynamic and competitive business environment

Practical projects produced by the students for the entrepreneurship course are concrete manifestations of the levels of the Revised Bloom's Taxonomy (RBT) applied throughout the course. The projects, explicitly directed at SDGs 6 and 10, had the students going through the cognitive levels of the taxonomy, ranging from recalling essential knowledge to the higher development of original solutions. The RBT integration provided a scaffolded framework that guided students' cognitive growth through the entire project development process lifecycle, from ideation to BMC and competitor research, peer review, and presentation final (as covered under the Methodology section).

The first project, the smartphone application for tracking home water usage (Fig 1), is an apt illustration of the use of a number of RBT levels. At the Remembering level, they recalled fundamental water conservation principles, sustainability concepts, and app functionality essentials. At the Understanding level, they comprehended the specific problem of household water wastage and articulated how data analysis would empower users. The Applying level was manifest in that students used this knowledge towards designing app functionalities, user interfaces, and integrating algorithms for personalized recommendations. Analyzing occurred as students balanced user data trends and possibly considered different recommendation methods. The Evaluating stage was integrated in the BMC feasibility studies and peer review mechanisms. Last but not least, the Creating level materialized in synthesizing diverse knowledge components—water management, technology, user experience, and business strategy—into a fresh, functional application with the aim of creating a real-world impact.

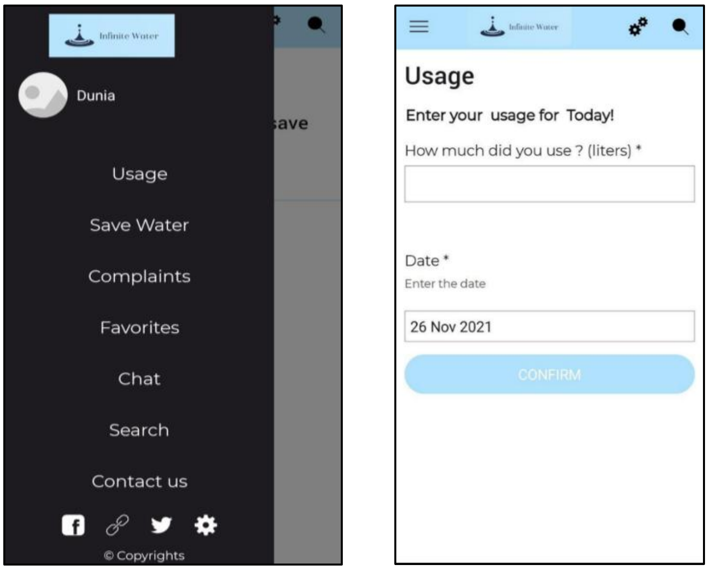

Fig1: Smartphone App for household water consumption

Similarly, the "Kidney Couch" dialysis patient mobile application (Fig 2) demonstrates the evolution of the taxonomy. Reminiscing involved recalling specific health problems of hydration in dialysis patients and basic healthcare app requirements. Students demonstrated Understanding by seeing the vital relevance of precise regulation of hydration and how Customer Relationship Management (CRM) principles could be used to enhance patient engagement in a healthcare setting. Application of knowledge was realized through the incorporation of certain features such as monitoring water intake and applying dietitian-endorsed nutritional guidance into a CRM-based interface. Analysis was required to contrast the needs of this specific patient population from how the features of the app were organized in response. Evaluation was realized through feasibility testing (BMC) and potential peer review. The Design of the specialized program, combining health monitoring and nutrition counseling tailored for a vulnerable subgroup, is the summit of cognitive synthesis by the students.

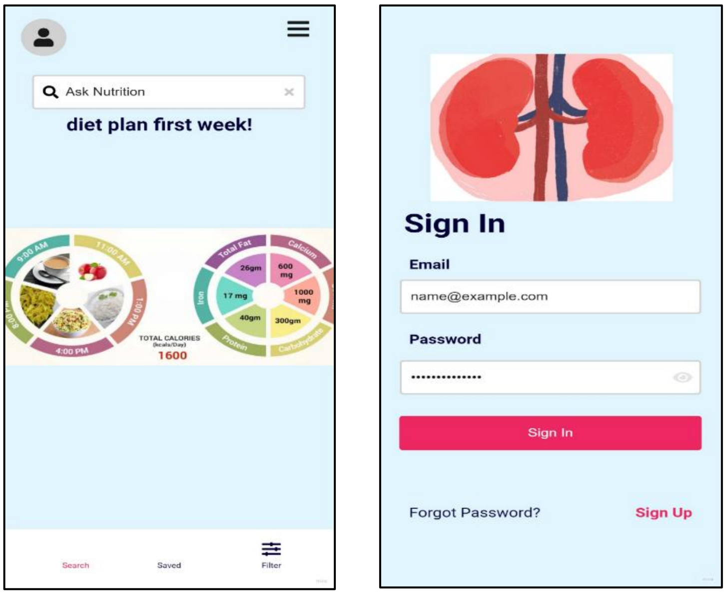

Fig 2: Kidney Couch

The third task, an interactive website for promoting overall water conservation (Fig 3), also illustrates the RBT model. Students began by Remembering information about water conservation importance, distribution timetable, and web-based billing systems. They demonstrated Understanding by gaining knowledge of how to develop dynamic sites and integrating diverse information streams effectively for community awareness. Application was the stage where website functionalities were created, user interfaces were designed, and information on schedules was integrated with billing functionality. Analyzing could have been testing out user needs for diverse website functionalities or establishing the effectiveness of information presented. The Evaluation phase was incorporated through the BMC process. The Website Design as an integrated system, integrating monitoring tools, information resources, and administration activities within a single accessible interface to facilitate sustainable practice, is the climax of the students' higher-order thinking.

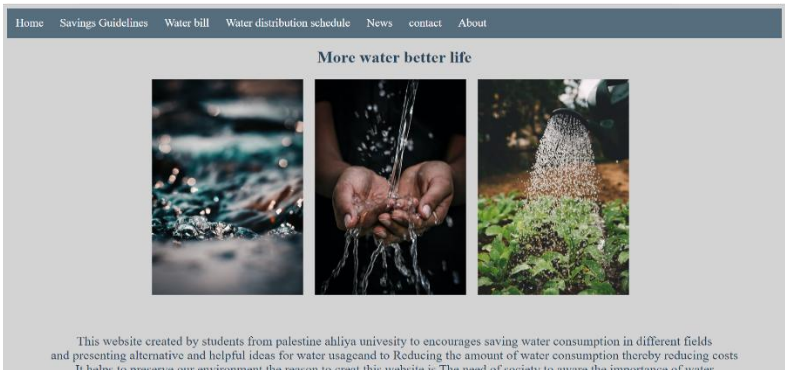

Fig 3: Water Conversation Websit

Collectively, these projects illustrate how Revised Bloom's Taxonomy was effectively implemented into learning. The scaffolding process ensured that the students not only produced outputs but engaged extensively with the content in more advanced levels of cognitive complexity. Each stage of project work, from the initial concept (Remembering/Understanding) to successive tweaking (Applying/Analyzing) to final pitch and evaluation (Evaluating/Creating), mapped directly onto the RBT levels. This structured engagement not only cultivated the entrepreneurial practical competencies of market research, business planning, and prototyping but also the critical and creative thinking necessary for developing innovative solutions to practical issues within a global sustainability paradigm. Projects therefore come not just as commodities, but as evidence of successful deployment of the Revised Bloom's Taxonomy in orchestrating student thought and learning in an entrepreneurial environment.

4. Conclusion

In conclusion, the integration of Revised Bloom’s Taxonomy into entrepreneurship and innovation education for engineers has proven to be highly effective in bridging theory to practice. By applying Bloom's taxonomy as a framework, students were able to progress through various levels of cognitive skills, from remembering and understanding foundational concepts to applying, analyzing, evaluating, and ultimately creating innovative solutions in the real world.

Through this pedagogical approach, students gained not only theoretical knowledge but also practical skills essential for entrepreneurial success. They learned how to identify market opportunities, develop viable business models, conduct thorough market analysis, and pitch their ideas effectively to potential stakeholders. Moreover, they honed their critical thinking, problem-solving, and decision-making abilities, which are crucial for navigating the uncertainties of the startup ecosystem.

5. Recommendations

Based on the research findings, entrepreneurship education must expand taxonomy-based approaches throughout engineering departments. Curriculum developers must continually connect learning exercises to Revised Bloom's Taxonomy levels while incorporating real-world issues like SDG-based projects. Professors must be specially trained on incorporating cognitive structures in entrepreneurial education. Institutions must hire overall assessment rubrics that monitor higher-order thinking skills development. Comparative studies between taxonomy-based methodologies and traditional methods in the future will determine effectiveness. Education policymakers would do well to consider mandating cognitive complexity models in engineering entrepreneurship programs accreditation standards.

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