A Spiral Approach to Teach Value Propositions Using the NABC Framework in Core Engineering Courses

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***Abstract*—In recent years, entrepreneurial mindset has become a hot topic in engineering education. The core of the entrepreneurial mindset on which we focus is summarized succinctly by the three C's: Curiosity, Connections, and Creating value. This paper describes ways to use a tool within the engineering curriculum focused on creating value. Specifically, we utilize the Need-Approach-Benefits-Competition (NABC) framework developed by Stanford Research International to teach engineering students how to articulate value propositions. Our teaching approach involves multiple assignments or projects that expose students to the NABC framework in several core engineering courses, with each subsequent assignment building on the previous experience that the cohort of students has with the NABC framework (i.e., a spiral approach). We argue that such a spiral approach using the NABC framework is advantageous in order to instill a value creation mindset in engineering students.**

Keywords—value proposition; entrepreneurial mindset; NABC framework; entrepreneurially minded learning (EML); spiral approach.

I. INTRODUCTION

According to Peter Drucker, "There is only one valid definition of business purpose: to create a customer." Drucker also claims that a serious cost disadvantage may destroy a business and that business success is based on the creation of value and wealth [1]. The common definition of value relies on the price to quality ratio of a product or the difference between perceived benefits and perceived costs. It is a description of a customer's problem, the solution to it, and value from the customer's perspective [2]. It is customers who decide whether or not to purchase a certain product; therefore, innovations must be based on what customers truly value [3]. The term "customer value proposition" has become one of the most widely used terms in business management in recent years [4].

In [5], Gary Wnek explains that engineers play a key role in transforming ideas and inventions into innovations that create value for customers. First and foremost, engineers contribute to value creation with deep analytical thinking grounded in scientific principles. But successful innovation requires consideration of a broad set of issues (e.g., markets, customers, intellectual property protection, financing, and sustainability) and a broad set of skills (e.g., communication, teamwork, project management, and the ability to spot emerging opportunities) [5]. Engineering education, therefore, must teach burgeoning engineers how to be entrepreneurially minded so they can be key influencers in creating value [6].

An entrepreneurially minded engineer should be curious enough to be aware of important problems and explore promising opportunities to address those problems. The process of taking an idea to market requires connecting and combining multiple factors including resources, information, and personnel. To be successful and sustainable in the market requires true value creation for consumers. Value proposition formulation is necessary to attract the talent and resources needed to pursue the idea.

One methodology for formulating value propositions, developed by Stanford Research International (SRI), is called the Need-Approach-Benefits-Competition (NABC) framework [7]. The NABC framework starts with a clear articulation of the underlying Need the idea addresses. Next, the Approach to meet the need is described. The Benefits of the approach to the specific stakeholders must be highlighted, and should demonstrate a favorable benefit to cost ratio. Finally, the Competition should be analyzed to show how the idea improves upon the competing solutions. The NABC framework has been reported to be beneficial to engineering students in communicating exactly what is expected of them in a freshman-level course on engineering innovation and entrepreneurship [8].

This paper discusses a spiral approach to teach the NABC framework to students across several courses in the electrical and computer engineering curriculum. The spiral approach focuses on exposing the student to the NABC approach for value proposition formulation in multiple courses with increasing breadth and depth in each subsequent course. We argue that a spiral approach facilitates development of mindset, and specifically, that our spiral approach inculcates the value creation aspect of an entrepreneurial mindset. The choice of courses used in our spiral approach is not important, as the approach may be extrapolated and applied to other courses.

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Engineering curricula tend to be rigid in the sophomore and junior levels in order to cover the breadth and depth of engineering science needed for the discipline. A common side effect of the focus on engineering science is a reduction of student interest, which can affect student engagement and overall student performance. The approach described in this paper can be implemented easily in core engineering courses that are usually offered in the sophomore and junior years without taking a lot of class time. Our approach involves integrating value proposition formulation with design projects, laboratory assignments, structured debates, and idea pitches, which engage students with the course material.

The paper is organized as follows. Section II discusses the NABC framework in an engineering context. Section III details the spiral approach we have applied to instill a value creation mindset. Section IV concludes the paper and describes how NABC may be applied to research projects.

II. NABC Framework for Engineering Problems

The NABC framework is a valuable tool throughout the product lifecycle. While it is certainly a well-established tool to aid the business case of an idea, we argue that it is also an excellent tool to make the engineering case. Further, we argue that the engineering case should not be decoupled from the business case. An outstanding engineering solution that is unviable from a business perspective will never be realized.

Engineers do not just solve interesting or "cool" problems. Engineers solve *important* problems. Hence, the first step of the engineering design process – defining the problem – should involve a thoughtful consideration of the underlying need associated with the problem. Viewing the problem through the lens of "Need" highlights the humanity that should be present in the engineering design process and emphasizes the need for design empathy.

The concept of background research in the engineering design process has an enhanced meaning in the NABC framework. It is necessary not only to research the technical approaches (i.e., the "Approach" of the engineering case) that may be applicable to solve the identified problem. But, it is also necessary to research the target market that the "Need" addresses. Trends in the target market may hint at unpursued opportunities or suggest improvements to existing products that can be leveraged to create value. For a given technical approach, several implementation options may be available, and research is necessary to discern the best option given the constraints and nature of the problem. Extensive research is necessary to determine the "Competition" and to be able to articulate clearly the "Benefits" of the "Approach" compared to the competition.

Traditional elements of the problem statement may be readily used in the NABC framework. For example, the design constraints help to shape the "Approach" and may provide justification for superiority over the "Competition" (if one of the competing solutions does not meet all of the design constraints and is thus an unviable solution). The design criteria – or evaluation metrics – provide the measures by which the proposed solution (or idea) may be quantitatively compared to competing solutions (i.e., the "Competition"). Those evaluation metrics that demonstrate superiority may then be listed as "Benefits" of the "Approach" over the "Competition". While these traditional elements of an engineering problem statement are part of the "Approach", business elements should also be considered such as the business model and marketing strategy of the "Approach".

III. A Spiral Approach to Instill a Value Creation Mindset

The spiral approach we propose here involves the following categories of assignments: Design project with the "Need" given, design project without the "Need" given, lab report with a historical perspective, structured debate, and idea pitch.

Based on our experience with adopting teaching approaches, we believe it is critical to outline the grading and other logistics of the assignment categories that have been successful for us in order to improve the ability to adopt the NABC framework in different courses. Each category has a slightly different structure and the order in which the assignments are introduced to the students can affect the implementation framework for the assignment. Below we describe the assignment categories and implementation logistics based on the order the authors introduced the assignments to the cohort of students. The interested reader may find that mixing some of the implementation approaches may be more beneficial for their students.

Finally, we note that there are three courses in which the five different assignments were introduced: Electric Circuits (86 students across four sections, with Electrical, Computer, Mechanical, and Civil Engineering students), Signals and Systems (21 students across Electrical and Computer Engineering), and Communication Systems (15 Electrical Engineering students). Students taking Communication Systems are juniors at our institution, whereas the other two courses are taken at the sophomore level, with Electric Circuits serving as a prerequisite to the Signals and Systems course, which in turn serves as a prerequisite to the Communication Systems course. By using existing prerequisite chains, we have ensured the majority of students (other than transfer students or those out of sequence) have experienced the NABC framework in the desired sequence for our spiral approach. The first author teaches Electric Circuits and Signals and Systems, and the second author teaches Electric Circuits and Communication Systems.

A. Design Project with the "Need" Given

As an initial exposure to the NABC framework, students may be assigned a design project with a well-defined problem (given "Need"). For example, we assigned a signal conditioning design project in an Electric Circuits course, in which the problem was to map the range of a signal from an angular position sensor on a robotic arm to the input range of an Analog-to-Digital Converter (ADC). Students were assigned to groups of three or four students with each group containing students from different departments. The "Approach" used in the design solution may be limited as well, if desired. For example, we suggested that our students use operational amplifiers in their designs. The "Competition" may also be limited in this first exposure to the NABC framework by requiring students to design alternative viable solutions, and using the alternative solutions as the "Competition". Finally, the "Benefits" may be articulated in terms of the design criteria or evaluation metrics considered in the design, as outlined in Section II. For example, electric power, number of components, adjustability, and cost are possible criteria to make the case for the benefits over the competition in this first exposure of the NABC framework.

The first time the NABC framework is introduced it is beneficial to show a video introducing the method [9]. It is also beneficial to introduce an example of applying the NABC framework to articulate a value proposition. The example we used is from [7, p. 92] in which video on demand is pitched to a cable broadcast company, circa 2006. Between the project assignment introduction, NABC video, and example, a total of approximately thirty minutes of class time is needed. Since the project assignment introduction would still need to be presented without considering the NABC framework, the addition of NABC to the overall time required is only approximately 15 minutes of class. We believe this is a low cost for the many benefits of the NABC framework.

For design projects applying the NABC framework, it is beneficial to provide intermediate deadlines for separate deliverables of the project assignment. For example, we required a design alternatives document (worth 10% of the total project grade) to be submitted a few weeks prior to the final proposal (70% of the total grade). The final deliverable was a working prototype demonstration pitch (worth 20%) presented to the instructor the week after the proposal was due. Each deliverable had its own rubric for grading.

A major benefit of intermediate deadlines is the ability to provide substantial feedback to students during the design process allowing students to learn from failure. To take advantage of the instructor feedback, it must be timely. Hence, we made the design alternatives document due on a Friday and had it graded and returned by Monday, with a few weeks left to correct the mistakes made in the initial design.

The design alternatives document required at least two unique and viable solutions to the design, including analysis, simulation, and design criteria assessment including a bill of materials and cost breakdown from a circuit component supplier. For the bill of materials it is important to require the supplier part numbers so that the instructor may verify the accuracy of the bill of materials.

The second deliverable for the Circuits design project was the written product proposal. In the assignment handout, we outlined the required sections of the written proposal, including: Introduction, Problem Description, Alternative Solution with Analysis, Simulations, Cost Analysis, Value Proposition, Testing and Implementation, and Conclusions.

The final deliverable for the Circuits project was a working prototype demonstration pitch. The pitch was a 5-minute demonstration of the prototype for the superior solution. Students were required to articulate their NABC value proposition for their superior solution verbally to the instructor. In this case, students were not encouraged to step through each component of the value proposition in a mundane way. Instead, they were encouraged to briefly summarize the problem, describe the functionality of the two alternative solutions, enumerate the means to validate the design, and finally indicate which evaluation metrics led to the choice of the superior design and describe why those metrics were reasonable. The pitch was held during the lab period in the final week of the course.

B. Design Project without the "Need" Given

Once the NABC framework is understood by students, many of the simplifications described in the initial design project may be relaxed in subsequent assignments. Perhaps the most critical step of applying the NABC framework is to find an important need that has good market potential. Therefore, a natural next step in the spiral method is to limit the "Approach" but allow students to identify an important "Need" for this "Approach". For example, in a Signals and Systems course, the "Approach" could be limited to designing an analog electronic filter. Students may research signal filtering applications such as audio processing, anti-aliasing filters, or filtering in medical devices, to identify the "Need".

In the Signals and Systems project, students were allowed to self-select groups of three or four students and their topic. Once the topic was selected, the first deliverable was a problem identification document (worth 10%), in which the students were required to define the problem, identify the target market, "Competition" within the market, industry trends, relevant stakeholders, and provide market research to make the business case for the filtering application. For the problem identification document, it is beneficial for students to meet with a research librarian to help them find good market data. The second deliverable was an initial design document (worth 10%), which focused on a single design. The final deliverable (worth 80%) was a written product proposal, similar to the previously described design project.

In this project, the "Benefits" may be articulated in terms of the design criteria as well as identification of market opportunities. Multiple NABC value propositions were required of students to emphasize how the NABC message should be tailored to a specific audience. We focused on the investor and the end user as the two stakeholder audiences.

C. Lab Report with a Historical Perspective

For another exposure, the introduction section of lab reports may be substituted with an NABC-based historical perspective of topics studied in the lab. For example, we required student pairs in a Communication Systems lab to provide the historical perspective of various communication techniques from analog to digital. For each communication technique, students must identify the historical "Need" for that technique, discuss the "Approach" (e.g., the modulation technique, spectrum utilized, and antennae technology), and compare its "Benefits" and shortfalls to the previous generation communication techniques – the "Competition". The NABC-based historical perspective is particularly useful in any lab course that introduces several competing technologies or approaches that have multiple tradeoffs, so that there is no clear across-the-board, superior approach.

For the implementation and grading of the lab reports, we only required half of the labs to have a lab report. This allows the time for the student to perform the required research to properly write the NABC section of the report. After the first graded report, extensive feedback was provided to the student to reinforce the NABC framework and describe how to successfully articulate the historical perspective within the scope of the lab report. Since it is expected that the students will take some time to develop the skill to articulate the NABC historical perspective, the lowest lab report grade was dropped. The overall grading for the lab is entirely dependent on the lab reports, with the caveat that a student must attend all labs to pass the course. The breakdown of the lab report grade has four components: NABC section (40%), Procedure (15%), Results (30%), and Conclusion (15%).

D. Structured Debate

Another assignment that may be enhanced through the NABC framework is a structured debate. Students naturally must formulate a case for each competing approach or opinion when preparing for a structured debate, so the NABC approach simply provides the framework to do so effectively. For example, students in the Communication Systems course were asked to recreate the third generation (3G) cellular technology standards debate in which Code Division Multiple Access (CDMA) and Orthogonal Frequency Division Multiplexing (OFDM) were considered for implementation in the 3G standard. Such an open-ended question is a perfect fit for a structured debate that can be framed nicely with NABC.

For the debate format, the instructor should divide the class into two groups, assuming there are two competing approaches. In our case, one group advocated for CDMA, while the other advocated for OFDM. To make the debate more productive, it is critical for the instructor to select the students who participate in each group. The key to consider when dividing the groups is to try to allow each group to have some high performing students, some who are hands on, and some who are extroverted to allow for a lively debate.

Each group was assigned a leader who allocated the aspects of the NABC value proposition for their side to the members of their group. For the "Approach", the students assigned this aspect of the NABC value proposition prepared materials and notes that emphasized the key features of the "Approach", which were shared with the rest of the class. Although this material was not used directly in the debate, it was used for assessment in the final exam of the course.

For the grading of the debate, it is helpful to prepare a spreadsheet containing all the students' names, which enables the instructor to assess the debate as it progresses. For real-time assessment it is advantageous to use the check/check plus/check minus approach, in which a check prefix is assigned to each student providing comments in the debate. The check plus is assigned to a statement that is correct and aids the case made by their group. A check is assigned when a student's statement is not incorrect but it does not really improve the group's argument. The check minus is assigned to a statement that is incorrect or detrimental to the group.

E. Idea Pitch

Finally, we implemented an idea pitch using the NABC method in the Communication Systems course. Although it is possible to implement an idea pitch at any level, we applied it to a senior capstone project idea pitch. At that level, because of the previous exposures to NABC, students were able to articulate strong value propositions emphasizing the important "Need" their capstone idea would address, outline the "Approach" they planned to use, identify the "Benefits" of the approach and compare their approach to the "Competition". Students justified their problem using real-world data and market research, largely because they had become mature with applying the NABC method. Each student was asked to prepare a poster and deliver a five minute pitch of the idea, after which the instructor questioned them for two minutes.

IV. Conclusions and Reflections

This paper describes the NABC framework for creating value propositions in an engineering context and prescribes a spiral approach to exposing students to the NABC framework over several core engineering courses in order to instill a value creation mindset. Our spiral approach consists of five different assignment categories implemented across three different courses: Electric Circuits, Signals and Systems, and Communication Systems. The specific choice of courses is not important, nor is the specific types of assignments – to some extent. However, it is important to design the assignments to require a progressively deeper and more rigorous treatment of the underlying "Need", the engineering and business case of the "Approach", the "Benefits" of the approach relevant to the audience, and the "Competition".

The NABC framework may also be useful to faculty applying for externally funded research projects. For example, the "Broader Impact" requirement of NSF proposals could be enhanced and emphasized by a careful consideration of the "Need" for the research project. The "Approach" in this case is clearly the technical approach proposed in the work. The "Competition" is the related work in the literature. The "Benefits" of the "Approach" over the "Competition" must be successfully articulated to the reviewers and program director in order to get the proposal funded. More generally, the NABC framework can be used to improve technical writing.

In terms of assessment, we have rubrics and formative assessment tools, such as the check/check plus/check minus grading scheme, to assess whether students are achieving the value creation learning outcomes. However, an area of assessment we have not developed yet is assessing how the NABC aspects of the assignments affect student understanding of the course material and the core engineering technical student outcomes. Furthermore, longitudinal assessment of program outcomes has not yet been considered.

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