Scoping Design Parameters for Educational Software Development with the Entrepreneurial Mindset

John K. Estell and Stephany Coffman-Wolph
Electrical & Computer Engineering and Computer Science Department
Ohio Northern University
Ada, OH, USA
j-estell@onu.edu and s-coffman-wolph@onu.edu

***Abstract*—This Innovative Practice Full Paper presents a successful approach for scoping term project design parameters. Making connections between classroom material and real-world design has always been challenging for educators; while the technical bells and whistles tend to captivate students, there's a lessened interest in the business, customer, and societal aspects of design. However, one must remember that design is made for people. Accordingly, some programs incorporate service-learning into their curricula, usually in the junior or senior year. This paper presents two innovations: (1) using a first-year programming course as the service-learning venue where (2) elements of the entrepreneurial mindset are employed to scope the design of a software application project augmenting a client-specified theme. The entrepreneurial mindset models employed are the NABC, which helps designers develop a proposed solution, and the MVP, where an early prototype is created to avoid the risk of building something no one wants. Using these models helps teams to communicate their ideas with both clients and team members, and determine whether they are converging toward an acceptable and timely solution, creating value for others by designing software meeting identified needs. Multiple assessments have shown the effectiveness of this approach, with students appreciating having open-ended client-based problems. To facilitate adoption, a repository containing all instructional materials associated with this paper is available at the Engineering Unleashed website.**

Keywords— CS2, NABC, MVP, Service Learning, Entrepreneurial Mindset, Software Development, Lean Startup

I. INTRODUCTION

One of the more humorous signs potentially on display when entering a service-oriented establishment is shown in Fig. 1. The punchline is that the customer cannot have it all. If "good" and "cheap" are selected, then the service will take time; if "fast" and "good" are selected, then the service will be expensive; and if "cheap" and "fast" are selected, then the service will be of poor quality. Such signs are actually derivations from the Project Management Triangle ("Triangle"), developed by Martin Barnes in 1969 as a graphic aid to illustrate the relationship between the performance criteria of time, cost, and quality [1]. Sometimes referred to as the "Iron Triangle" or the "Triple Constraint," it can be depicted with the attributes represented either as vertices or as edges. Although it serves as a central concept of project management research, an examination of 45 years' worth of related publications revealed that only Time ("fast") and Cost ("cheap") are consistently identified as part of the Triangle. The third attribute, correlating to "good" on the sign, has been represented by concepts such as Quality, Scope, Performance, and Requirements [2]. Succinct critical examinations of the history and variations of the Triangle paradigm can be found in [2] and [3].

For purposes of this paper, the Triangle will be represented by the attributes of Time, Cost, and Scope based on the representation used within the book *A Guide to the Project Management Body of Knowledge (PMBOK)* [4], editions of which has been recognized as standards by both the American National Standards Institute (ANSI/PMI 99-001-2004, ANSI/PMI 99-001-2008) and the Institute of Electrical and Electronics Engineers (IEEE 1490-2011). The attributes are presented as edges as shown in Fig. 2 and are defined based on [5] as follows. *Time* is the total elapsed time, from assignment to completion, that it takes to perform the project. *Cost* encompasses all resource usage invested into the project, including work hours, which measures use of labor resources. Finally, *Scope* constitutes the features and functions that characterize the product, service, or result. While it is generally accepted that no model is perfect, this particular Triangle paradigm variant helps to illustrate the interrelationships that exist between Cost, Scope, and Time, in that for a project, if any one of these attributes changes, at least one other factor will probably be affected [4].

In an academic environment, the Time attribute is usually a constant based on the date when a project assignment is due. While the corporate environment might allow for slippage in a completion date, the end of an academic term generally serves as a hard constraint. Similarly, Cost has an upper bound based on the maximum expected amount of work hours to be

Fig. 1. A humorous sign

completed, which can be estimated as a function of the number of students assigned per team, the number of credit hours associated with the course, and the federal regulation specifying minimum expectations for the number of out-of-class hours spent per week per semester credit hour [6]. This leaves Scope.

In order for a class project to be successful, students must have a handle on the scope of their project. However, Scope is by far the fuzziest of these three attributes, as the definition of scope varies based on what project management text is being used, and is often expressed in qualitative terms that leave room for interpretation and subsequent misunderstanding [7]. Three aspects of scope emerge across the various definitions, with two of them explicitly recognized in the PMBOK [4]. *Product scope* are the features and functions that characterize a product, service, or result. *Project scope* is the work that needs to be accomplished to deliver a product, service, or result within the specified features and functions. To simplify matters in an academic setting, product scope is usually determined by the students, whereas the project scope is normally provided by the instructor. This allows student teams to focus on the tangible details of the deliverable, such as team charters, stakeholders input, requirements collection, and acceptance criteria. The instructor provides the general framework for the design process being employed, often through underlying network scheduling tools such as Gantt or PERT charts being used to derive appropriate milestones for setting intermediate project deadlines for moving teams forward through the project [8]. In short, product scope tells us what is needed, while project scope tells us how to get there [9]. The third aspect of scope mentioned in [7] is that of *boundaries*, as without some concept of boundaries one cannot determine if an activity or requirement lies inside or outside the scope of the project. Unfortunately, specifying project boundaries is difficult due to the presence of various uncertainties, such as the lack of a clear specification of what is required, lack of experience with the activity, and optimism bias [10]. While some of this can be mitigated for in an academic environment, such as instructors identifying clients for a particular project that is known to be feasible, student teams are still tasked with handling responsibilities that they are not yet proficient in, such as understanding needs and identifying requirements [11]. Additionally, when scope is not properly defined, documented, or controlled, the phenomenon of *scope creep* can occur. Thus, it is important to ascertain needs and demystify requirements through stakeholder-related activities to help establish a scope baseline that guides the team's management efforts for the duration of the project [12]. Otherwise, the team runs the risk of the scope either being defined too large to begin with or inflating due to scope creep.

The impact of scope creep can be readily visualized via the broken Triangle in Fig. 3. As Time for an academic project is fixed, its represented length cannot change. As Cost is a function primarily of team size and credit hours, its length can grow, but it also has an upper bound. Thus, if Scope is defined poorly or is affected by scope creep, its excessive length results in the team attempting to apply additional human resources toward the project. This causes the Cost attribute to eventually reach its upper limit, beyond which project failure results. One way to physically demonstrate this scenario is to consider a physical manifestation of the Triangle where the Time edge is made from a brick, the Cost edge from a rubber band, and the Scope edge from Silly Putty. Each has differing degrees of elasticity: bricks cannot be stretched whereas a little Silly Putty can create a highly elongated ribbon. Nestled in-between, a rubber band can only be stretched so far, beyond which it breaks - signifying project failure.

As this paper focuses on the use of models adopted from the application of the entrepreneurial mindset in determining project scope, it is appropriate at this time to provide an introduction into the entrepreneurial mindset. Engineering education has been criticized for stressing technological knowledge while ignoring the needs of business and industry; instilling an entrepreneurial mindset within engineering curricula is one means of addressing this issue [13],[14]. Among the organizations that have worked on fostering entrepreneurial mindset ecosystems within engineering education has been the Kern Entrepreneurship Education Network (KEEN) [15]. Launched in 2005, KEEN originally consisted of 11 private US Midwestern universities with ABET-accredited undergraduate engineering programs; this Network now consists of over 50 member institutions focusing on entrepreneurial mindset development as a means to describe value of entrepreneurial education for all engineering students, regardless of their career paths [16]. As defined by Engineering Unleashed, an entrepreneurial mindset (EM) is a habit of mind geared toward action. It is a learned behavior; a way of thinking about the world and acting upon what is seen, empowering people to identify opportunities and create value in any context. Engineers equipped with the entrepreneurial mindset understand the bigger picture, recognize opportunities, evaluate markets, and learn from mistakes, thereby leveraging entrepreneurial ways of thinking to create and deliver value to others [17], [18]. Prior research has shown positive effects of engineering entrepreneurship programs on both GPA and retention [19], of entrepreneurial mindsets on student design problem framing [20], and on students' entrepreneurial self-efficacy [21].

The remainder of this paper is organized as follows. Section II introduces the NABC model, while Section III introduces the MVP model. Section IV presents an overview of the course and term project for situational context. Section V discusses the introduction of the models, and Section VI discusses their

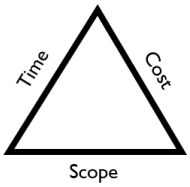

Fig 2. The Project Management Triangle

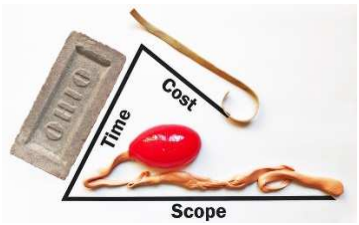

Fig 3. Scope creep breaking the Triangle

subsequent application in a client-focused design along with an exercise for discerning tasks associated with the initial client meeting. Section VII discusses the adaptation of the models as part of the Critical Design Review process. Quantitative and qualitative results are presented along with their discussion in Section VIII, and the authors' subsequent conclusions are given in Section IX. Finally, Section X presents where resources mentioned within this paper are available for download.

II. The NABC Model

Value creation is the process of identifying and delivering to customers solutions to their important needs that are better than that provided either by the competition or by available alternatives [22]. The delivered value does not necessarily need to be monetary; for example, it could be societal. Unfortunately, few are trained to be productive value creators [22]. As part of their book documenting revitalization efforts at SRI International, Carlson and Wilmot described their Five Disciplines of Innovation, two of which are *Important Needs* and *Value Creation* [23]. Their book emphasizes that one should work not on what they personally find interesting, but on addressing the needs of the customer, preferably through use of tools that can create customer value fast. One such tool developed by SRI International is the NABC model. This tool is based on a simple premise: that a project can be initially vetted by addressing four fundamental questions, where the answers can be conveyed in simple terms in any order to a knowledgeable person to help determine the potential for delivering customer value [23]. First, what is the important customer and market *Need*? Second, what is the unique *Approach* for addressing this need? Third, what are the specific *Benefits per costs* that result from this approach? Fourth and finally, how are these benefits per costs superior to the *Competition's and the alternatives*? Collectively, these four questions form a value proposition on the basis of *N*eed, *A*pproach, *B*enefits, and *C*ompetition; this is shortened to NABC for convenience. Although there are various meanings associated with the term *customer value*, the focus in an educational environment is normally placed on what constitutes value for the customer, which can be in terms of either value perceived or received by customers [24]. This correlates well with the following philosophical quote from the German industrial designer Dieter Rams: "You cannot understand good design if you do not understand people; design is made for people" [25]. By focusing on this understanding as a major tenet of design, engineering programs can better promote the taking of general education courses as the means for students to better understand the human condition.

While there is no set agreement within management practice regarding what constitutes a value proposition or what makes one persuasive [26], it should aim to provide distinct, focused benefits that solve specific customers' problems [27]. The NABC model has been shown as benefitting first-year engineering students in an introductory Innovation and Entrepreneurship course in providing an approachable framework [28], and as a conduit for improving technical writing skills as part of a spiral approach to teaching value propositions throughout a curriculum [29]. NABC also provides a more systematic approach to value proposition discernment, and encourages the development of value propositions that are understandable, as the communication of ideas to those outside one's field of interest can make a notable difference between an idea's acceptance or rejection [23], [30].

III. The MVP Model

Although popularized in the book *Lean Startup* by Ries [31] and considered to be the most important step in the Lean Startup methodology, the Minimum Viable Product (MVP) model was first developed by Robinson in 2001 [32]. The MVP concept has morphed somewhat over its relatively brief existence, covering applications in both the entrepreneurial mindset and agile development environments. While Ries defines it as a way to "help entrepreneurs start the process of learning as quickly as possible," he focuses on the model providing "the fastest way to get through the Build-Measure-Learn feedback loop with the minimum amount of effort" [31]. However, Lenarduzzi notes that the term now generally refers to "an early prototype" or "an early version of a product" [33]. There is general agreement that the essential purpose of the MVP process is to get something that works in front of users in order to learn something that can then be fed back into an iterative design process [31].

There has been a wide range of MVP applications within academic settings, including experiences outside of traditional coursework such as bootcamps [34], workshops [35], and summer programs [36]. MVP tends to be applied in junior- and senior-level courses, often as part of a hands-on, project-based learning approach combined with other EM concepts to provide students with real-world experiences [37-40]. However, there are examples of earlier offerings within engineering/computing curricula present within the literature. One institution includes MVP in their sophomore-level software engineering course, noting that while such a course is traditionally a junior-level offering, the importance of the skills gained being needed, important, and practiced warrants the early introduction [41]. Another institution introduces the MVP concept along with other business tools as parts of the Lean Startup model in their first-year introductory engineering course [42]. While some have students develop only to the MVP stage [35], [37], [40], others use the MVP as a step towards a completed design [39], [42]; however, all emphasized the importance of the MVP and provided students with appropriate tools for its implementation.

IV. Situational Context: CS2 Term Project

The computer science program at Ohio Northern University (ONU) offers an introductory programming sequence consisting of two 4-semester credit hour courses. The fall course (CS1) introduces basic programming constructs, using C++ to implement small programs covering sequence, selection, and iteration concepts. This is followed by the spring course (CS2) that is offered in Java and introduces the object-oriented paradigm, graphical user interfaces, and event-driven programming. Both courses are offered in a 15-week semester format, consisting of three 50-minute lectures and one 165-minute laboratory session every week.

For over a decade, the CS2 course has culminated with a term project focused on developing educational software applications. An open-ended, service-learning approach involving clients was incorporated into the project in 2014, and EM concepts were introduced the following year [43]. A

retrospective study conducted in 2018 validated the successfulness of the approach [44]. Clients have ranged from education majors, to local elementary school teachers, to those involved in STEM outreach. Changes in clientele has occurred primarily due to program growth overwhelming the number of clients available. Currently, CS2 is in its second year of partnering with student organizations housed within the ONU College of Pharmacy in support of their community healthcare outreach efforts [45]. This collaboration benefits from the emphasis placed by that college on service-learning as part of their 6-year Doctor of Pharmacy curriculum.

The term project is conducted during the second half of the semester. Teams of 3-4 students are formed using CATME Team-Maker [46], with team formation based primarily on similarities of schedule, lab section, and willingness to work evenings and/or weekends. Once formed, teams use CATME's Team Charter for setting their operational ground rules and creating repositories for their code and related documents. As discussed in the following sections, teams actually work on two projects. The first project is internal to the course and is used to introduce development tools while "stress testing" the team. Following the (hopefully) successful completion of the first project, teams then work together with their real-world client.

V. Introducing the Models: Oregon Trail

Actors don't suddenly appear on stage to perform a play; athletes don't suddenly appear at a stadium to complete in a match. Actors rehearse; athletes practice. Similarly, in order to apply these models with a client's project, it's a good idea to practice beforehand in an isolated "sandbox" environment, where the course instructors act as clients and present a *persona* that represents an end user and a *scenario* that presents a need. By employing this approach, any mistakes made by the teams are made internally, thereby limiting potential embarrassment.

For several years, the scenario has involved an aspect of an team-based activity contained within an educational resources guide regarding the Oregon Trail [47]. In this scenario, the persona is a sixth-grade student in a Social Studies class, learning about the western migration undertaken by American pioneers during the 1840's. Unfortunately, in this scenario the persona's teammates are not taking things seriously, forgetting things mentioned earlier in class, and dismissing the persona's suggestions, causing the persona to withdraw from the class activity. To help address the situation, each team is asked to develop a variant of the original text-based Oregon Trail simulation game [48], in which a design is created, but only partially implemented. Essentially, the foci of this assignment are (1) to help students coalesce into functional teams while (2) learning how to apply the just-introduced project scoping tools. Teams are first tasked with developing an NABC by examining the wants, needs, and fears experienced by the persona in terms of both the scenario and the persona's personality preferences as provided by a given Myers-Briggs Type Indicator (MBTI) inventory. From this, a user story map is created that envisions what the persona would experience by participating in a fully implemented version of an Oregon Trail simulation. Through this experience, teams are asked to determine what user story map attributes belong in an MVP implementation through use of a provided worksheet, placing features contained in the user story map into "Must Do," "Might Do," and "Removed" bins. Once the NABC and MVP documents are finalized, the teams then develop CRC cards and corresponding UML diagrams for specifying their application's design classes as part of an agile-based development process. Teams internally assign tasks and accept responsibility for implementing specific classes and/or methods. The goal is to develop an application that conveys just enough of the essence of a fully-functional program. Once completed, an elevator pitch based on the NABC is made to the instructor, and immediately followed by a demonstration of the MVP application, thereby allowing students to both practice their oral presentation skills and obtain formative feedback prior to interacting with a real-world client.

All team members are required to perform reflective individual performance reviews for all team members via CATME for instructor review. Additionally, each team member performs a SWOT analysis of their team's efforts, which are then shared collectively with the team and a team-level SWOT report developed. This report is then used to help identify points of friction within the team that need to be addressed prior to working with the client.

VI. Applying the Models: Ideation

Following the Oregon Trail exercise, programming students transition into working on the client-based project. The course instructors work with the clients beforehand to develop a one-page problem statement. Following the announcement of the project specifics and distribution of this statement, students perform an ideation exercise in preparation for the initial client meeting [49]. Designed to be completed within one class period, each student individually starts the meeting preparation process by recording short responses to prompts regarding what tasks should be performed before the meeting, what agenda items should be covered in the meeting, and what follow-up tasks will need to be completed after the meeting. Students then reflect on three additional prompts, recording their responses to (a) what three questions you would most like to have answered at the meeting, (b) what three things must you do to be both prepared and professional at the meeting, and (c) what three qualities do you have to offer that will please the client. In the next stage of the process, team members collaborate, sharing their findings and recording those that are in common with at least two team members on Post-It notes. Individual findings deemed by the group to be appropriate for inclusion are recorded on Post-It notes, which are then organized on a whiteboard (an online whiteboard with simulated sticky notes was used during the pandemic) into one of three specific collection categories: preparation tasks (before the meeting), agenda items (during the meeting), and follow-up tasks (after the meeting). The final phase begins with the teams being presented with the Client Meeting Checklist, which provides an external perspective toward client meeting preparation based on interviews with capstone faculty and industrial advisors [50]. This checklist both affirms those items already present on the Post-It notes, and provides additional suggestions for inclusion. Teams then discuss and rearrange each set of Post-It notes until it culminates in an agenda for the meeting plus list of tasks to be performed both beforehand and afterward. This approach has been successfully used at multiple institutions for scoping the parameters of the initial client meeting.

Based on their topical research and their interactions with the client, teams are charged with developing two preliminary design proposals. Similar to the user story mapping approach practiced earlier, teams provide two differentiated visions as to how a software application can address the client's need. This approach forces teams to consider multiple alternatives, which is the first step ("Widen Your Options") in the WRAP process promoted in the book *Decisive* by Chip Heath and Dan Heath for making better workplace choices [51]. To employ the second step in the WRAP process ("Reality-Test Your Assumptions"), the preliminary proposals are reviewed by both instructors and clients using a project proposal rubric to help both discern the best features of each proposal and counteract any confirmation bias held by one or more team members. This step provides recommendations that express selecting one proposal over another and/or combining features from both proposals. Theoretically, both proposals might be rejected, forcing the team to start over; thankfully, such dual rejection has not happened. This feedback is then employed by the teams in writing the formal design proposal, which includes applying the NABC model to identify the salient features of the design. While relatively short and on the order of just a couple of days, the time involved in waiting for feedback forces each team to wait, thereby attaining distance from their ideation before making their actual design decisions. This - "Attain Distance Before Deciding" - is the third step in the WRAP process. Teams also have to apply the MVP model at this time to specify the scope of the application; in particular, what features need to be present in an executable minimum viable project software application.

The team has approximately one week to have their MVP implemented and demonstrated as part of the next design review with the client. As part of this meeting, the client provides written formative feedback through use of a Software Application Evaluation Rubric furnished by the course instructors, using dimensions measuring aesthetics, navigation, understanding, correctness, user attention, and alignment with client objectives. This incorporates the final step of the WRAP process: "Prepare to Be Wrong". Formative feedback is critical at this stage, as the team is attempting to ascertain the client's true wants and needs through a product demonstration, and the odds are against having everything figured out correctly on the first try. By obtaining feedback as quickly as possible with as little implementation effort as possible, the team thereby minimizes risk, as the cost investment to date (from a student work-hour standpoint) is relatively small. It's only appropriate that risk is further minimized by the instructors not recording anything other than a "completion score" for having performed the requested task by the specified deadline. By informing all parties that the rubric is being used at this time for formative feedback, the potential of a client "holding back" on negative comments to avoid being the cause of a poor score is eliminated. By encouraging discussions and constructive criticisms, this design review also starts the WRAP process over again, as suggestions can be bounced back and forth between team and client, thereby widening potential options for the next round of development. Teams continue forward, steadily progressing toward the next major milestone, while keeping both client and instructor appraised of their progress through both submission of progress reports and, as warranted, additional design review meetings with either the instructor or the client.

VII. Adapting the Models: Design Review

If the presentation of this term project is viewed as a form of storytelling, the sandbox exercise constitutes the *exposition* stage, the initial client meeting serves as the *inciting incident* stage, and the *rising action* stage is found within the iterations of applying agile design in developing the application. Thus the story steadily builds into the *climax* stage with the Critical Design Review (CDR), held in the format of a software application fair, called "App Fair" for short. Conducted similarly to a science fair, the App Fair is usually held early in the penultimate week of the semester, where each team meets with judges recruited from groups external to the course, including alumni, faculty, industrial advisory board members, practicing professionals, and staff. In response to the pandemic, the spring 2020 course offering successfully transitioned to an online version of the App Fair, which had the added benefit of allowing alumni from across the country to participate, including those working at Amazon, Google, and SpaceX, which made a considerable impression on the students [45].

For each round of judging, the team is required to first present an *action pitch* explaining their project, followed by a demonstration of the (nearly-completed) application. An action pitch is meant to solicit the next steps following a value proposition and is based on the following elements: an opening *hook* to get the audience's attention, the NABC-based *value proposition*, and the *close* to prompt the action that is wanted next [22]. In this context, the close is meant to solicit the input of the judges both during and after the demonstration regarding the extent to which the application's requirements have been met. Multiple rounds of judging are used to ensure that teams have to engage in meaningful conversations with a wide range of audiences, including those versed in programming and those versed in the client's subject material, which aligns well with ABET's Criterion 3 calling for an "ability to communicate effectively with a range of audiences" [52]. Accordingly, during one judging round students might have to show their code for how a particular feature was implemented, and in the next round display sufficient subject knowledge derived from client interactions and accompanying research. The NABC thus serves here as a tool in defining scope for the judges' interactions with the team, focusing their efforts toward constructive criticism that can then be used to improve the software application.

The team receives multiple modes of feedback from the CDR. First, there is the real-time feedback obtained through conversation with each group of judges. To help capture this information, teams are required to designate a scribe whose task is to record notes of these conversations; a typed version of the notes must be submitted the following day. A more formal feedback approach is also employed via the judges' use of the Software Application Evaluation Rubric. Implemented as a Google Form, judging data can be quickly tabulated and returned to the team shortly after the completion of the App Fair. One notable difference is that the Rubric is now used for both formative and summative evaluations. From a formative perspective, it is still providing feedback that can be incorporated into the next design iteration. However, as the design is supposed to be essentially complete, scores are obtained from the rubrics and applied toward the project grade. Finally, with the transition of the CDR to an on-line

environment, teams are required to record one judging session for submission to their instructor, who now has the relative luxury of watching and revisiting the student presentations within each video at a convenient time, using rubrics to assess the quality of both the NABC value proposition employed and the team's overall oral presentation performance.

Returning back to the storytelling allusion, the team is now entering the *falling action* stage, dealing with the information received from both judges and instructors to determine what modifications need to be made to the application prior to delivery. However, the limited amount of Time and Cost left when approaching the end of the term adds a new complication, creating additional pressure for getting the Scope right. This can be accomplished by adapting the MVP as a sieve through which the various inputs are processed into "Must Do," "Might Do (if time permits)," and "Removed (not important or not enough time)" bins. The document created from this MVP application is due two days after the App Fair, thereby encouraging teams to quickly move into the *resolution* stage, allowing approximately one week for implementing the "Must Do" modifications. The project concludes with the *denouement* stage, primarily by the team's transferal of their completed application to the client. The team must also submit their source code files, evaluate their teammates' performance plus their own via CATME, and perform post-activity surveys for capturing both qualitative and quantitative assessment data.

VIII. Results and Discussion

Regarding the focus of this paper, the working hypothesis is that, if the team performed well on the one leg - *i.e.*, Scope - of the Project Management Triangle predominantly under their control, then their Triangle would essentially be complete, resulting in a successful project demonstration and subsequent delivery of a useful software application. This section first presents the assessment results obtained from the App Fair, which is then followed by indirect assessments of individual students' understanding of the MVP and NABC models.

A. App Fair Assessment Data

As part of the CDR process, each App Fair judge completed the aforementioned Software Application Evaluation Rubric based on each team's demonstration. The six evaluated dimensions were scored using an augmented single point rubric format [53]. The distinguishing characteristic of the single point rubric is that, for each criterion, only the expected level – or "single point" – of performance is provided; this provides clarity of expectations for the students while relieving instructors from creating performance descriptors capturing and rating various aspects of lower performance that characterize a typical analytic rubric. To allow for both performance assessment and the assignment of scores, each of the four performance levels is given a weighted value: *Lacking* (0), where the evidence for that dimension is either weak or missing; *Developing* (3), where the evidence suggests that performance improvements are needed; *Proficiency* (4), where the expected (and therefore defined) level of performance is demonstrated; and *Mastery* (5), where there is evidence of having exceeded the stated performance expectations. The weights within parentheses are set such that the assessment of an item proficient in all dimensions results in a score of 80%, the traditional boundary between B- and C-level work. To attain a score associated with A-level work of 90% or above, sufficient mastery must be shown in at least half of the dimensions, with proficiency demonstrated in the remainder.

A total of 28 judges participated in the 2021 App Fair, generating 55 separate assessments across 14 student teams, with each project individually assessed by an average of four judges. Table I presents the summative results of this assessment, both overall and aggregated by team, and categorized by performance level. The Developing level is split for this paper into High and Low halves to incorporate alignment with the traditional A-B-C-D-F grading schema. The original summative data indicates that the teams generally have performed well, with 55% of the judges' cumulative assessments recorded at the Proficiency or Mastery level, with the bulk (36%) of the remaining assessments in the Developing-High category. When this data is aggregated by teams, 57% are performing at a proficient level, with the remainder in one of the two Developing levels. To better discern where potential shortcomings are located, the breakdown of the quantitative results of the judges' feedback by each assessed dimension are presented in Fig. 4. In this data, the judges indicated that the teams performed best in the areas of focusing on the objectives of the application, closely followed by conveying the material on mental health in an understandable fashion while being easy to navigate and free of noticeable errors. Lower scores were obtained in the aesthetics and using gamification to maintain user attention dimensions. This can be somewhat expected, as aesthetics-related concepts such as color theory and Gestalt principles are not usually covered in a first-year programming curriculum, and the sensitivity associated with mental health issues adds a sizable level of difficulty in applying basic aspects of gamification principles. However, some clients wanted their application to look "professional" - but using their definition - while also providing full user accessibility by eliminating graphics and animations, applying monochrome color schemes, and using only standard fonts. While laudable, this comes at the cost of forsaking the aesthetic aspects of user interface design,

Table I. Original and adjusted results of CDR assessment

Performance Levels (boundary minimum)	Original		Adjusted	
	Overall	Team	Overall	Team
Mastery (90%)	12	0	22	1
Proficiency (80%)	18	8	15	10
Developing-High (70%)	20	4	13	1
Developing-Low (60%)	0	2	2	2
Lacking	5	0	3	0

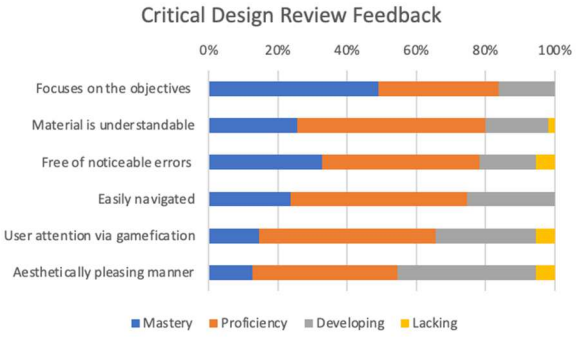

Fig 4. 2021 App Fair feedback rankings by dimension

where color, type, and imagery are essential components. This also helps explain the lower gamification scores as many teams were told by their client to forego this functionality. If the aesthetics and gamification dimensions are removed from the evaluation, purely for comparative purposes as shown in the Adjusted columns of Table I, team results noticeably improve, reducing in half the number of teams classified as Developing. The overall results are more nuanced, with a shift towards Mastery observed but still containing a low performance cluster.

Each assessed dimension also included a text box for obtaining qualitative feedback. The comments received generally supported the quantitative results, with statements such as "Seems to meet client requirements" and "The app is right on target for what the client wanted! Great work on this." A few groups received critical comments regarding their action pitch presentation, such as it was "Hard to evaluate how the objectives were satisfied as they weren't explicitly shared." Some judges also commented on the design not conforming with their expectations, as "I was expecting to see an interface that was geared towards children and young adults."

Each team's submitted video was viewed for purposes of instructor assessment of the NABC-based value proposition contained within the action pitch. A five-dimension rubric was used to ascertain the extent to which teams addressed needs, approach, benefits, competition, and logical presentation of content. As shown in Fig. 5, the majority of teams were rated at the Proficiency level or better with their NABC action pitches; however, some teams struggled with the Competition dimension.

B. Student Survey Assessment Data

Indirect assessment was also conducted by asking the 49 students enrolled in the spring 2021 offering of the CS2 course to complete voluntary pre- and post-activity on-line surveys regarding their opinion of the pedagogical approach used and their perceived understanding of the NABC and MVP concepts. The pre-activity survey consisted of collecting demographic data and ascertaining whether students had any prior knowledge of either model. Of the 19 students who returned the pre-activity survey, only one indicated having prior knowledge of MVP, and none were aware of NABC. The post-activity survey contained additional questions regarding perceptions on the effectiveness of the models and pedagogical techniques used in their introduction and application. The quantitative questions employed a 7-point Likert scale, with 1 indicating "strongly disagree" and 7 indicating "strongly agree." First, as shown in Fig. 6, the 20 post-activity survey respondents generally agreed that the sandbox environment provided a good introduction toward learning how to apply the MVP and NABC models. The models were also considered to be effective in both presenting ideas to, and receiving feedback from, the client.

While qualitative questions were also included with the post-activity survey, students were only asked to address what they believed could be improved upon for the in-class coverage of the two models. Regarding the presentation of the NABC model, only 11 students responded, and some of those responses were supportive along the lines of "all was covered well," and "I think everything was covered just fine." Of the constructive criticism received, there were calls for more coverage over Competition, with one mentioning that "it is difficult to simulate in a class environment" and another requesting additional coverage in "identifying the competitors" and incorporating that information into the benefits per cost analysis. There were also comments concerning the methodology, requesting more information as to "how to better utilize it to our benefit" and "how to present the NABC" along with a better explanation of its purpose. Similarly, only 9 responses were received regarding the MVP model, and again many of the responses were supportive, including "all was explained well," and "I believe each part made sense the way it was presented." One student's response was very verbose in its support: "I think it was covered very well, and the applications were shown very well. It was integrated well, and allowed us to utilize the method to get better feedback and convey our ideas to our client more effectively." Of the constructive criticism received, one student suggested an additional one or two days of coverage "would have made a huge difference," whereas two students expressed concern regarding what an MVP should contain. One student essentially asked "what is too little and what is too much" to include in an MVP, while the other student asked for additional guidance concerning "what items to focus on in a MVP," and if the conclusion of the MVP process was with the client or when the identified minimal features were fulfilled.

IX. Conclusion

Two models commonly used in entrepreneurial mindset endeavors were presented to students in a first-year CS2 programming course for assisting with the scoping of the design parameters for a client-based term project. By using a sandbox

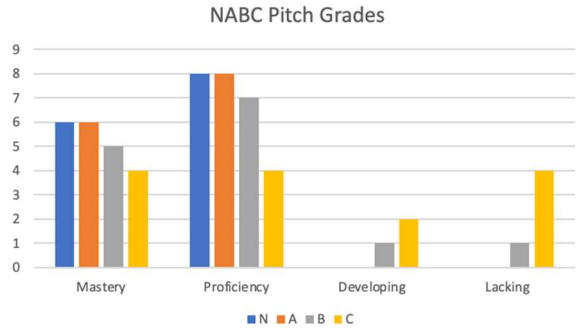

Fig 5. Instructor assessment of the NABC pitch for each dimension

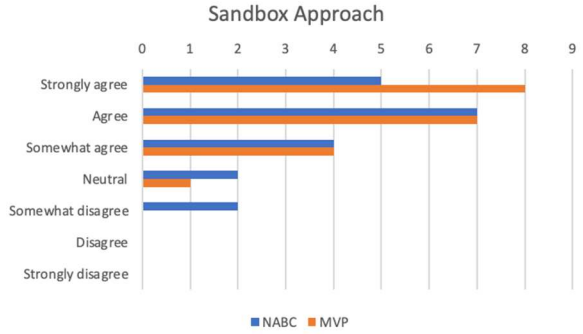

Fig 6. Student responses to introductory sandbox approach

approach for their introduction, teams were able to practice using the NABC and MVP models prior to meeting with their client. The introduction of two additional tools – the "Three Intelligences" exercise and the Client Meeting Checklist – allowed teams to properly prepare for their initial client meeting and focus greater attention on assessing wants and needs. Students then applied both EM-sourced models in new situations: using NABC as part of an action pitch to provide scope in soliciting judges' input, and MVP for identifying suggestions from the Critical Design Review that can be implemented within the limited amount of time remaining in the term.

While both direct and indirect assessment data provided clear evidence of student learning from the pedagogical approaches employed, items of concern and opportunities for improvement were also noted. Due to its more tangible nature, the benefits of the MVP model were more readily identified and embraced by students than that of the NABC model. Additionally, employing the MVP model eventually involves writing code, which for any programmer is comforting, whereas employing the NABC model often involves making an oral presentation, which is rarely in any student's comfort zone. Developing new laboratory exercises for examining scope, including reinforcing NABC concepts, delivering mini action pitches, covering an expanded definition of competition, and practicing MVP discernment, are thus planned for the next offering of CS2. In particular, more work is needed in helping students properly identify the "competition," including available non-software solutions and those alternative designs developed by the team as part of the proposals delivered to the client. To address issues regarding some clients not allowing teams to pursue various project outcomes, it falls upon the instructors to "educate the client" by proactively defining and setting guidelines regarding the scope of their interactions with the programming students.

At course end, teams of first-year programming students successfully applied EM in crafting software applications that met client needs. Applying the NABC and MVP models for quickly discerning an appropriate project scope played a major role in that success, providing an early - and unique - experience in using their chosen profession in delivering meaningful value to others.

X. Available Resources

Practice-oriented papers should readily provide interested readers with those materials developed "in-house" to assist in supporting adoption efforts. To that end, a "Card" - *i.e.*, an information repository - has been created for this paper on the Engineering Unleashed website operated by KEEN [54]. This card provides instructional materials for covering the MVP and NABC models along with all of the materials mentioned in this paper, including those developed "in-house" such as the Software Application Evaluation Rubric. These materials can be freely downloaded, reviewed, adopted, and if desired modified, by anyone for use in their courses under the Creative Commons CC BY-NC license [55].

Acknowledgment

The proposal for this study, entitled "Students' views on adapting business tools for software development and communication with clients," was granted exempt review status (under category #1: educational strategies, curricula, or classroom management methods) by the Institutional Review Board (IRB) of Ohio Northern University under protocol # SC-EN-022621-1.

References

[1] M. Barnes. "Some Origins of Modern Project Management - A Personal History." PMFORUM, Connecting the World of Project Management - Viewpoints.https://web.archive.org/web/20060813162842/www.pmforum.org/viewpoints/2006/08_4.htm (accessed Apr. 1, 2021).

[2] J. Pollack, J. Helm and D. Adler, "What is the Iron Triangle, and how has it changed?," *Int. J. Managing Projects Bus.,* vol. 11, no. 2, pp. 527-547, May 2018.

[3] R. Vahidi and D. Greenwood, "Triangles, trade-offs and success: a critical examination of some traditional project management paradigms," in *Construction Facing Worldwide Challenges: CIB Joint International Symposium*, A. Cerić and M. Radujković, Eds. Sept. 27-30, 2009, pp 927-936.

[4] Project Management Institute, *A Guide to the Project Management Body of Knowledge*, 3rd ed. Newtown Square, PA, USA: Project Management Institute, Inc., 2004.

[5] S. A. Devaux, Total Project Control: A Practitioner's Guide to Managing Projects as Investments. 2nd ed. Boca Raton, FL, USA: CRC Press, 2015.

[6] 34 C.F.R. § 600.2 (2020).

[7] B. Bigelow. (Oct. 2011). Scope—mastering the fuzzy constraint. Presented at PMI® Global Congress 2011—North America, Dallas, TX, USA. [Online] Available: https://www.pmi.org/learning/library/scope-understanding-change-perspectives-managing-6177.

[8] H. R. Kerzner, Project Management: A Systems Approach to Planning, Scheduling, and Controlling. 12th ed. Hoboken, NJ, USA: John Wiley & Sons, 2017.

[9] "Product Scope vs. Project Scope," Villanova University Project Management Resources. https://www.villanovau.com/resources/project-management/product-scope-vs-project-scope (accessed Apr. 11, 2021).

[10] R. Atkinson, L. Crawford and S. Ward, "Fundamental uncertainties in projects and the scope of project management," *Int. J. Project Manage*., vol. 24, no. 8, pp. 687-698, Nov. 2006, doi: 10.1016/j.ijproman.2006.09.011.

[11] M. N. Mirza, Z. Pourzolfaghar and M. Shahnazari, "Significance of Scope in Project Success," *Procedia Technol.*, vol. 9, pp. 722-729, 2013, doi: 10.1016/j.protcy.2013.12.080.

[12] D. Orlando. (Oct. 2013). Scope and stakeholder management: pain points, perils, and prosperity. Presented at PMI® Global Congress 2013—North America, New Orleans, LA, USA. [Online] Available: https://www.pmi.org/learning/library/stakeholder-management-pain-points-perils-prosperity-5955.

[13] G. W. Davis and G. DiGiuseppe, "Infusing an entrepreneurial mindset into mechanical engineering courses: Two case studies," *2017 IEEE Global Engin. Educ. Conf. (EDUCON)*, 2017, pp. 1354-1358, doi: 10.1109/EDUCON.2017.7943023.

[14] J. B. Hylton, D. Mikesell, J.-D. Yoder and H. LeBlanc, "Working to Instill the Entrepreneurial Mindset Across the Curriculum," *Entrepreneurship Educ. Pedagogy*, vol. 3, no. 1, pp. 86-106, Jan. 2020, doi: 10.1177/2515127419870266.

[15] J. Blessing, K. Mekemson and D. Pistrui, "Building An Entrepreneurial Engineering Ecosystem For Future Generations: The Kern Entrepreneurship Education Network," in *Proc. 2008 ASEE Annu. Conf. & Expo.*, Pittsburgh, PA, USA, 2008, doi: 10.18260/1-2—3488.

[16] A. Huang-Saad, C. Bodnar and A. Carberry, "Examining Current Practice in Engineering Entrepreneurship Education," *Entrepreneurship Educ. Pedagogy,* vol. 3, no. 1, pp. 4-13, Jan. 2020, doi: 10.1177/2515127419890828.

[17] L. Bosman and S. Fernhaber, *Teaching the Entrepreneurial Mindset to Engineers.* Basel, Switzerland: Springer International Publishing, 2018.

[18] The Kern Family Foundation, "Welcome to Engineering Unleashed." Engineering Unleashed. https://engineeringunleashed.com (accessed Apr. 11, 2021)

[19] M. W. Ohland, S. A. Frillman, G. Zhang, C. E. Brawner and T. K. Miller III, "The effect of an entrepreneurship program on GPA and retention," *J. Eng. Educ.*, vol. 93, no. 4, pp. 293-301, Oct. 2004.

[20] E. Kim and G. J. Strimel, "The Influence of Entrepreneurial Mindsets on Student Design Problem Framing," in *IEEE Trans. Educ.*, vol. 63, no. 2, pp. 126-135, May 2020, doi: 10.1109/TE.2019.2918253.

[21] N. Duval-Couetil, T. Reed-Rhoads and S. Haghighi, "Engineering students and entrepreneurship education: Involvement, attitudes and outcomes," *Int. J. Eng. Educ*., vol 28, no. 2, pp. 425-435, 2012.

[22] C. Carlson, L. Polizzotto and G. R. Gaudette, "The "NABC's" of Value Propositions," in *IEEE Eng. Manage. Rev.*, vol. 47, no. 3, pp. 15-20, Sept. 2019, doi: 10.1109/EMR.2019.2932321.

[23] C. R. Carlson and W. W. Wilmot. *Innovation: The Five Disciplines for Creating What Customers Want*. New York, NY, USA: Crown Business, 2006.

[24] J. B. Smith, J. Brock and M. Colgate, "Customer Value Creation: A Practical Framework," *J. Marketing Theory Pract.*, vol. 15, no. 1, pp. 7-23, 2007.

[25] D. Rams. "Dieter Rams: Design by Vitsœ." Vitsœ Design Dieter Rams. https://www.vitsoe.com/files/assets/1000/17/VITSOE_Dieter_Rams_speech.pdf (accessed Apr. 11, 2021).

[26] T. Carter and D. Diro Ejara, "Value innovation management and discounted cash flow," Manage. Decis., vol. 46, no. 1, pp. 58-76, Feb. 2008, doi: 10.1108/00251740810846743.

[27] J. Lindič and C. Marques da Silva, "Value proposition as a catalyst for a customer focused innovation," *Manage. Decis.*, vol. 49, no. 10, pp. 1694-1708, Nov. 2011, doi: 10.1108/00251741111183834.

[28] C. R. Carlson and J. J. Schaufeld, "Technical Education in the Innovation Economy," in *Shaping Our World: Engineering Education for the 21st Century*. Hoboken, NJ, USA: Wiley, 2012 , pp. 151-178.

[29] H. J. LeBlanc and F. Hassan, "A spiral approach to teach value propositions using the NABC framework in core engineering courses," *2017 IEEE Frontiers in Educ. Conf. (FIE)*, 2017, pp. 1-5, doi: 10.1109/FIE.2017.8190583.

[30] J. Rajamaki and L. Leppävaara, "Learning in higher education by European Framework projects Laurea's study module: "International innovation work of information systems"," *2015 IEEE Global Eng. Educ. Conf. (EDUCON)*, 2015, pp. 954-960, doi: 10.1109/EDUCON.2015.7096088.

[31] E. Ries, *The Lean Startup*. New York, NY, USA: Crown Business, 2011.

[32] F. Robinson. "A Proven Methodology to Maximize Return on Risk." SyncDev. http://www.syncdev.com/minimum-viable-product (accessed Apr. 11, 2021).

[33] V. Lenarduzzi and D. Taibi, "MVP Explained: A Systematic Mapping Study on the Definitions of Minimal Viable Product," in *42th Euromicro Conf. Softw. Eng. Adv. Appl. (SEAA)*, Limassol, Cyprus, 2016, pp. 112-119, doi: 10.1109/SEAA.2016.56.

[34] O. Cico, L. Jaccheri and A. N. Duc, "Towards Designing an Experience-based Course around Innovation Bootcamps — A Cohort Study," *2020 IEEE Frontiers in Educ. Conf. (FIE)*, 2020, pp. 1-9, doi: 10.1109/FIE44824.2020.9274225

[35] D. Christe, J. J. Bhatt, D. G. McGee and R. Wolfish, "Entrepreneurship, Engineering, Innovation, and Libraries: Empowering Innovators with Information," in *Proc. 2017 ASEE Annu. Conf. & Expo.*, Columbus, OH, USA, 2017, doi: 10.18260/1-2—28290.

[36] J. Schoepf, S. M. Gillespie, A. Trowbridge, A. Cook-Davis, K. Peña, C. Argenti and D. J. Laxman, "A Summer Program Focused on Developing an Entrepreneurial Mindset in the Context of the NAE Grand Challenges for Engineering," in *Proc. 2020 ASEE Annu. Conf. & Expo.*, Virtual, 2020, doi: 10.18260/1-2—34063.

[37] V. Galluzzi, C. A. Berry and Y. Shibberu, "A Multidisciplinary Pilot Course on the Internet of Things: Curriculum Development Using Lean Startup Principles," in *Proc. 2017 ASEE Annu. Conf. & Expo.*, Columbus, OH, USA, 2017, doi: 10.18260/1-2—27486.

[38] C. Kitts and A. Mahacek, "The Santa Clara University Maker Lab: Creating the Lab, Engaging the Community, and Promoting Entrepreneurial-minded Learning," in *Proc. 2017 ASEE Annu. Conf. & Expo.*, Columbus, OH, USA, 2017, doi: 10.18260/1-2—29011.

[39] E. Pluskwik, E. Leung AND a. Lillesve, "Growing Entrepreneurial Mindset in Interdisciplinary Student Engineers: Experiences of a Project-Based Engineering Program," in *Proc. 2018 ASEE Annu. Conf. & Expo.*, Salt Lake City, UT, USA, 2018, doi: 10.18260/1-2—30565.

[40] S. Mohagheghi, "A Pedagogical Approach for Developing an Entrepreneurial Mindset in Engineering Students," in *Proc. 2020 ASEE Annu. Conf. & Expo.*, Virtual, 2020, doi: 10.18260/1-2--34031

[41] J. R. Vallino and B. Basham, "A Re-look at the Introduction to Software Engineering Course," in *Proc. 2018 ASEE Annu. Conf. & Expo.*, Salt Lake City, UT, USA, 2018, doi: 10.18260/1-2—29718.

[42] A. Ferrar and P. Watkins, "A Connected Course Approach for Introduction to Engineering Problem Solving," in *Proc. 2019 ASEE Annu. Conf. & Expo.*, Tampa, FL, USA, 2019, doi: 10.18260/1-2—31949.

[43] J. K. Estell and D. Reeping, "Providing Authentic Experiences in the First Year: Designing Educational Software in Support of Service Learning Activities," in *Proc. 2015 ASEE Annu. Conf. & Expo.*, Seattle, WA, USA, 2015, doi: 10.18260/p.24617.

[44] D. Reeping and J. K. Estell, "Partnering to Develop Educational Software Applications: A Four-year Retrospective Study," in *Proc. 2018 ASEE Annu. Conf. & Expo.*, Salt Lake City, UT, USA, 2018, doi: 10.18260/1-2—30859.

[45] J. K. Estell, S. Coffman-Wolph, J. Sieg and M. Musser, "Supporting Pharmaceutical Healthcare Outreach: A Culminating First-Year Programming Experience," in *Proc. 52nd ACM Tech. Symp. Comput. Sci. Educ. (SIGCSE '21)*, 2021, pp. 376–382, doi: 10.1145/3408877.3432470

[46] R. A. Layton, M. L. Loughry, M. W. Ohland and G. D. Ricco, "Design and Validation of a Web-Based System for Assigning Members to Teams using Instructor-Specified Criteria," *Adv. Eng. Educ.*, vol. 2, no. 1, pp. 1-28, Spring 2010.

[47] Bureau of Land Management, "The Oregon Trail: An Education Resource Guide - 2016 Edition." https://www.blm.gov/teachers/activities/documents/Oregon_Trail_Education_Resource_Guide.pdf (accessed Apr. 11, 2021).

[48] D. Rawitsch, "Oregon Trail," *Creative Computing*, vol. 4, no. 3, pp. 132–139, May–Jun. 1978. [Online]. Available: https://archive.org/details/creativecomputing-1978-05.

[49] B. K. Jaeger-Helton, S. Howe and J. K. Estell, "Meeting the Client: Learning the Capstone Student's Perspective through the Three Intelligences Methodology," unpublished.

[50] J. K. Estell, S. Howe, B. K. Jaeger-Helton, S. Sangelkar, K. D. Kinzli and D. Rand, "Client Interaction Tools: Supporting Student Professionalism on Client-based Capstone Design Projects," *Int. J. Eng. Educ.*, vol. 35, no. 6, pp. 1953-1968, 2019.

[51] C. Heath and D. Heath. *Decisive*. New York, NY, USA: Crown Business, 2013

[52] ABET, "Criteria for Accrediting Engineering Programs, 2021 – 2022." https://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2021-2022 (accessed Apr. 30, 2021).

[53] J. K. Estell, H. M. Sapp and D. Reaping, "Work in Progress: Developing Single Point Rubrics for Formative Assessment,"in *Proc. 2016 ASEE Annu. Conf. & Expo.*, New Orleans, LA, USA, 2016, doi: 10.18260/p.27221.

[54] J. K. Estell and S. Coffman-Wolph, "Scoping Design Parameters for Educaional Software Development with the Entrepreneurial Mindset." Engineering Unleashed, https://engineeringunleashed.com/card/2738.

[55] Creative Commons, "Attribution-NonCommercial 4.0 International (CC BY-NC 4.0)." https://creativecommons.org/licenses/by-nc/4.0/ (accessed May 5, 2021).