



The Product Archaeology Canvas

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A Product Archaeology Canvas

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1 Introduction

Engineering as a profession strives to benefit society through the applications of technology and science. Meaningful contributions from engineers are therefore achieved by balancing technical proficiency with a wider understanding of society^{1,2}. More recently, entrepreneurship has arisen as a method for weaving an understanding of society^{3,4,5,6,7}, and in particular the way businesses view society, into the education of engineers^{8,9,10,11,12,13}. As engineering educators, strive to produce “industry-ready” engineers - graduates who use their technical expertise to bring value to an existing organization^{14,15}. Although reliable numbers are difficult to come by, it seems clear that there are more engineers entering established industries than creating their own start-up companies. As educators we have responded by focusing on fostering an “entrepreneurial mindset” - a collection of skills, knowledge and attitudes that will enable engineers to both amplify the value they provide to large industries (intrepreneurs) and form their own start-up companies (entrepreneurs).

A common theme that arises for both intrepreneurs and entrepreneurs is how to make complex decisions given incomplete information. In this paper a Product Archaeology Canvas (PAC) will be introduced as a pedagogical tool to uncover how complex decisions are made in bringing a product to the market. The PAC is a combination of three distinct sources. *Product* dissection is the disassembly of a product with the goal of understanding why technical decisions were made^{16,17,18,19}; The PAC expands the decision making process beyond technical decisions. *Archaeology* strives to create a coherent narrative from incomplete information²⁰; Student must fill in gaps in the publicly available information to create a plausible narrative for the actions of a company in bringing a real product to market. A *Canvas*²¹ is a visual tool that can show non-linear interactions between various components²²; Relationships between many dimensions of a decision can uncover the complexities underlying most important business decisions²³.

The primary goal of the PAC is to guide students in using their technical talent to be holistically value oriented. The PAC may also be of valuable outside of the classroom as a way as a means of conducting a holistic competitive analysis and as a mechanism for generating and scoring ideas that may provide new value. The case for product archaeology as a pedagogical technique has been argued elsewhere²⁴. Therefore the focus of this paper will be on the canvas.

To begin, general concepts of the canvas will be discussed, followed by how it can be used as a pedagogical tool in both a backward and forward pass. A case study will be presented to illustrate one specific implementation of the general approach. A comparison will then be made between the Business Model Canvas (BMC)^{21,25}, which is focused on new business creation, and the PAC which aims to deconstruct the decisions of an existing business. Assessment of the approach from both a student and industry leader perspective will be presented. The article concludes with some preliminary best practices, speculation on alternatives, limitations and future work.

2 The Product Archaeology Canvas

The idea of product archaeology has been explored elsewhere^{26,27,28,29,30,31}, but this is the first introduction of the canvas.

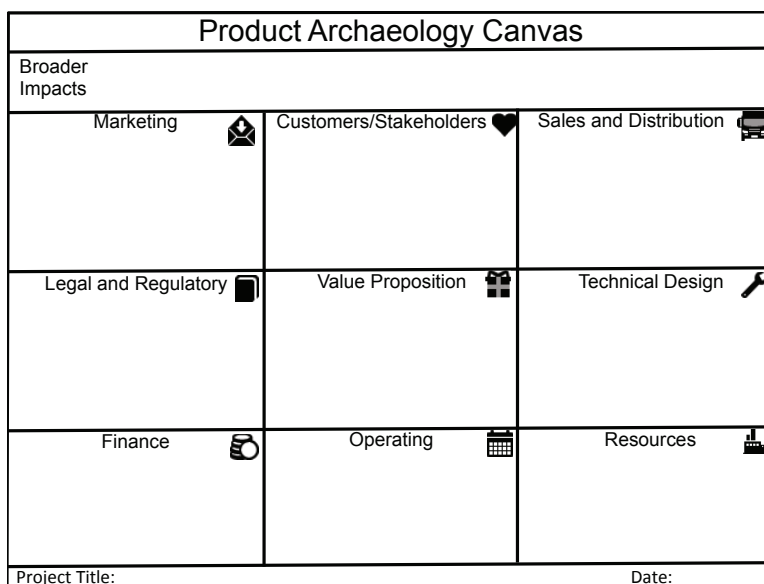


Figure 1: The graphical representation of the Product Archaeology Canvas (PAC)

The visual aspect of the canvas is important in that it organizes business concepts in a way that is digestible, but still retains the inherent non-linear relationships that are important in complex decision making. Cognitively it is important that all boxes appear on one page²² to aid in the integration of these non-linear relationships. All boxes are roughly the same size to reinforce the idea that value can come from anywhere within a company. For example, a distribution innovation may provide more overall value to a company than one in finance, marketing or product development. The value proposition is placed in the center of the canvas as the anchoring concept in decision making, and is the box through which other areas communicate. For example, finance may provide value to legal and regulatory by providing funding for intellectual property protection.

The initial names and divisions between boxes were derived through a combination of activities. First, traditional technology management books as well as business articles were surveyed (see

citations for a selection). Second, informal conversations with industry leaders were used to refine the canvas. Their feedback was largely that specific industries may split some boxes, or combine some boxes, or make some boxes larger than others, but that overall the canvas represents the high-level Jobs To Be Done³² by any technology-focused industry. Furthermore, within a given box, the exact content will depend upon the particular business and product. Appendix A provides some topics that were introduced, but these are not meant to be prescriptive or exhaustive.

3 Using the Canvas as a Pedagogical Tool

The canvas can be used in two different pedagogical ways, either independently or together. The first is a backward-looking pass where students must unearth the decisions a company has already made in bringing a specific product to market. The second is a forward-looking pass where students propose future decisions the company may make to increase the value of an existing product.

3.1 Backward Archaeology

Backward Archaeology is most akin to what happens in the field of archaeology. Information is collected (excavated) but is incomplete and so a plausible narrative is created to tie together all of the pieces. To collect information, a readily-available product is dissected^{16,17,18,19}. The goal, however, is not simply to take apart the device to understand how it works, but rather to learn how a high-level executive may balance the competing demands of many divisions within their company. Value is considered very broadly (e.g. technical, marketing, financial) and from multiple perspectives (e.g. shareholders, customers, distributors). Students need to be active about how they gather data. Some data is easily obtainable online. Some data is only discovered through cold calls, site visits or online chats with tech support. Students are often surprised that companies are in fact eager to talk to students. Just as an engineer uses systems thinking to decompose a product from a technical perspective, students engaged in backward archaeology are challenged to use systems thinking to decompose all of the elements within each box of the PAC.

What arises is more than simply a historical record of the decisions that were made. The visual aspect of the canvas highlights the entire business ecosystem that surrounds a product. Missing data becomes easy to identify. Stories emerge to account for the data collected. Whether these stories are “right” or not, is largely irrelevant - they instead become hypothesis as to what is happening within a company. In some cases, students uncover a company that is aligned to support the product. In other cases, students discover misalignment. It also becomes clear that “innovation” (for the sake of innovation) does not always bring the greatest value. Yet, a company that is constantly lagging behind their competition (in any of the boxes) will eventually lose out in the marketplace.

3.2 *Forward Archaeology*

Forward archaeology is most closely aligned with the concept of entrepreneurship - making decisions and taking actions now to yield future value for a specific product from an existing company. In execution, students must first generate new ideas (diverging phase) and then vet those ideas (converging phase). Although a third phase (action) could easily be added, I have not implemented this phase in my classes. Many frameworks exist for generating new ideas^{33,34,35,36}, and there are also excellent resources for vetting ideas once they are created (*e.g.* Pugh Matrix, House of Quality, SWOT). The PAC, however, is a unifying framework that can guide both diverging and converging phases.

In the diverging phase, students are asked to put on various hats or faces^{37,38,34,39,40} where they can identify the pains of the Chief Marketing Officer, then the Chief Financial Officer, then the Chief Operations Office, and so on around the canvas. From these various perspectives they generate ideas that would add value that is relevant to their specific product. What emerges are a range of ideas on how to extract more (or potentially new) value from an existing product.

The converging phase of forward archaeology is to use the canvas as a mechanism for vetting ideas. For each idea students move throughout the canvas again to explore the value added (or perhaps detracted) from the perspective of each box. I have found that students can very quickly vet an idea, in perhaps 5 minutes, to determine if that idea is viable from a more holistic point of view. They can then perform a deep dive into the four or five ideas that seem most promising. I often have them dive deeply into ideas by having them perform a SWOT analysis for each element of the PAC. With this multi-dimensional SWOT analysis in hand, students are more aware of the possible barriers to executing each idea, and are in a good position to iterate on their forward-looking strategies, tactics and actions. The next step is for students to put on the hat of the Chief Executive Officer and make the best holistic decision on what actions to take. This leading idea becomes the one that they will pursue for their forward archeology proposal.

Throughout forward archaeology students make many discoveries. For example, complex decisions must take into account the current and projected economic environment, regulatory landscape, bleeding-edge technology, and movement of competitors, as well as the internal competencies, product portfolio and dynamics within the company. They see the domino effect that can occur when a change is made in one place in the company (*e.g.* an entire retooling of manufacturing facilities). And they also discover that in many cases the best value is gained not through a technical change but through some other division of the company. Lastly, many of them discover that several value-added changes may be combined together synergistically.

3.3 *Case Study: Medical Device Assessment and Development*

The canvas was first implemented in a junior-level half credit biomedical engineering course and contained much of the outcomes and topics listed in Appendix A. The details of the course are outlined in a previous conference proceeding²⁴. Briefly, students engaged in backward archeology on an over-the-counter medical device for the first half of the semester and then turned to forward

archaeology for the second half of the semester. The PAC appears in the syllabus of the course to show students the topics we will cover. It should be noted that the PAC was initially created for a course focused on medical devices, a field with one of the highest financial and regulatory barriers to entry. This will become significant when the PAC is compared to the Business Model Canvas.

In the backward archaeology, teams of three students put themselves in the shoes of the company five years before their product was launched. The challenge is to excavate information on topics such as FDA clearance, consumer trends, supply chains, intellectual property, market dynamics, manufacturing, budgets, packaging and distribution. In fact, they complete an analysis in all boxes except for the technical design box - I want them to make more honest guesses as to the technical functions rather than investigate them in the device. The goal is to first view design through the perspective of all other boxes. For example, they will find patents, marketing material, financial statements and other documents that will hint at the technical design. It is only after moving through all of the other boxes that teams perform a technical dissection to complete their knowledge of their product. They are prompted to compare their guesses with what they actually found.

The goal of backward archaeology is to piece together a clear and consistent narrative of how decisions were made as their product was moving from idea to the market. Along the way they find holes in the story and must attempt to fill them with further research or their best guesses. The mid-term assignment is a formal presentation of the backward archaeology on their product. This backward archaeology then becomes a set-up for the forward archaeology phase - a way to knowing the product, the company, the customers and the strategies that align (or do not align) with the company values and mission.

The forward archaeology goal is to propose clear and coherent actions (driven by a higher level strategy) to guide product development for the next five years. As such, the implementation of their plan should be easily justified by someone doing backward product archaeology on their product idea, five years from now. After experiencing the complete backward archaeology of their device, they have many of the tools that will be useful to create a forward archaeology proposal. The final assignment is a formal pitch to the CEO of the company of their new idea and why it will provide the best holistic value for the company. Some students propose minor modifications, others propose a radical rethinking of their product, and still others propose to discontinue a product and focus energy on an entirely new product. Along the way, they often discover new tools and concepts. For example, they may realize the power of leaving the decision path purposely unclear (e.g. Coke's secret recipe) to secure a long-term competitive advantage in the marketplace. Likewise, they may consider how new technologies might become powerful marketing tools (e.g. Snapchapp, future iPad and SmartPhone Apps) or how to estimate the costs associated with changing suppliers, manufacturing practices or distribution.

3.4 Annotated Slides

There are many formats that could be used to report out the findings of backward archaeology and the proposals of forward archaeology. I have chosen annotated slides because they were men-

tioned repeatedly by industry leaders and consultants as a way to report out significant findings and recommendations. The target audience for annotated slides is typically a high-level executive who has decision making power. Such executives want a high level perspective, but also want to be able to drill down into specific details as needed. Annotated slides, unlike a long linear report, provide just such a communication means. There are many online sites that provide directions on preparing annotated slides^{41,42,43,44}. These recommendations often include:

- Summary graphics with text annotations. Often with more information per slide than what is recommended for presentation.
- Strong recommendations (often highlighted) that are action oriented and measurable
- Extensive notes that support the data or explain a rationale for a recommendation

I have found that the preparation of annotated slides provokes students to dive deeply into each of the boxes of the canvas, yet also forces the selection of the most important big-picture aspects for presentation. Annotated slides prepare them very well for the pitch-like format of the presentation (10 minutes of presentation and 15 minutes of questions). The presentation is simply meant to lay out the big ideas and seed a more extensive discussion. An added benefit of the PAC is that it can help students organize their presentations. I typically advocate preparing one slide per box of the PAC and then determining which boxes to combine into one slide and which boxes can therefore be allocated two slides. The result is a 10-slide presentation.

4 The Product Archaeology Canvas Compared to the Business Model Canvas

The Product Archaeology Canvas was inspired by the Business Model Canvas (BMC). In this section I point out the similarities and differences between the two frameworks. We will start with the similarities.

Both the BMC and PAC are broadly value-focused in that no one aspect of business inherently takes precedence over any other. Both advocate the formation of hypotheses, accompanied by data collection, as a way to drive forward the decision making process. This is an especially effective tool in environments where it is not possible to have complete information. The BMC has always advocated the open-source creation of derivatives that more specifically target particular arenas where value can be added. For example, there is now the Innovation Canvas⁴⁵ and the Business Model You⁴⁶ that aims to help individuals understand their own strengths, weakness, goals. Later in this paper are some ideas of how the PAC might be modified. The PAC and BMC also provide one framework that can be used to generate, vet, and improve upon ideas to prepare them for the market. Both are easily adapted to traditional engineering courses that might range from the first year to graduate study and both naturally touch upon many ABET outcomes. Both the BMC and PAC advocate a deep dive into a business, not simply as an on-paper academic exercise but in practice. Lastly, both tools have pedagogical value within the classroom and practical applications in the wider business world.

There are at least three significant differences, however, in the purposes and execution of the PAC compared to the BMC. First, the BMC only looks forward because it is about business creation.

This is expected since the entrepreneurial approach assumes that the company values, mission, culture, stakeholders and history are being developed as part of the product launch. The BMC is therefore most applicable to products that do not yet exist and will hopefully be the first product of a promising new business. The PAC on the other hand has both a backward and a forward pass. The backward pass is critical when innovating from within an existing company because it enables the forward pass to align ideas with the existing history, culture, values and mission. The PAC is most useful to improve upon and reenvision products that already exist. The pedagogical consequences of the BMC and PAC are therefore different. The backward pass in the PAC allows students to observe how others have made complex decisions before trying to make their own decisions in the forward pass. The same is not true for the BMC.

Second, the BMC and the forward pass of the PAC may appear similar on the surface, but underneath they have some significant differences. Starting up a technology business requires different skills and knowledge (perhaps different attitudes as well) than being an innovator within an existing business^{47,48}. For example, the way an entrepreneur and an intrapreneur thinks about the financial aspects of a product will be very different. The advantage of the BMC is the flexibility that it affords an entrepreneur during business growth (e.g. to radically pivot if needed). Understanding the external barriers to executing one's vision becomes the focus. The advantage of the PAC is that it facilitates making good decisions in an internal environment that is constrained by path dependancies, existing processes, stakeholders, mission, values and culture. Understanding these internal barriers to executing one's vision becomes the focus.

Third, the BMC as explained in *Business Model Generation* is more holistic in both the types of start-up businesses and the range of considerations. Unfortunately, in practice^{49,50} the BMC is not well equipped for entrepreneurship in fields where there are high barriers to entry. Experimentation and "failing forward" works well in markets that are fluid, have low regulatory and manufacturing barriers, and few ethical questions. But most mature markets, which compose the vast majority of positions available to entry level engineers, are not of this type. The airline, automobile, medical device, chemical processing, food, agriculture and biotechnology industries cannot adopt a "fail forward" attitude. In fact, in many fields it takes years to legally test a functional prototype in the real world. The PAC also has an explicit box, spanning the entire top of the canvas, for broader impacts. This type of box is not present in the BMC, despite being mentioned throughout *Business Model Generation*. For the types of large launches coming from big companies it is critical to consider broader impacts before the launch.

The BMC and PAC have many strengths, and in many ways their strengths overlap. But they have each been created and tuned for a particular purpose, and as a result they foster the development of different skills, knowledge and attitudes.

5 Assessment

The pedagogical effectiveness of product archaeology is ongoing. A preliminary assessment has been performed by surveying students in the Spring 2014 offering of the Medical Device Assessment and Development course (BMEG 408) at the conclusion of the course and halfway through

their senior capstone the following year. A preliminary investigation of the industrial applicability of product archaeology as a way to teach intrapreneurship has also been conducted by surveying nine industry leaders. Bucknell University's Institutional Review Board approved both data collection methodologies.

5.1 Course Assessment

All students in the Spring 2014 offering of BMEG 408 (n = 15) were surveyed at the conclusion of the course as part of the university mandated evaluation. Students were asked to reflect on the strong and weak points of the course in open-ended questions. Product Archaeology was not specifically targeted in any questions. Below are representative comments, grouped by theme.

In general, students found the approach to be somewhat disorienting, but found the focus on value and the use of a real device to be helpful.

- "I found 408 to be extremely helpful in determining and thinking about value. Throughout the semester I kept referring back to this in order to gain a clearer understanding of the components of a company".
- "It was helpful to have an actual physical device to work with".
- "We had to do a lot of this ourselves, which led to strong comprehension".
- "Getting a hold of some information was found to be impossible. This was frustrating".
- "We had to call up companies to try to discover their distribution channels, which was a good experience".

The focus on communication, and in particular the annotated slides, was perceived to be strength.

- "The phase I and II project presentations were a good way to incorporate all that we learned throughout the semester".
- "The annotated slides were a big help".
- "While they were time consuming the annotated slides helped me analyze and understand design at a much deeper level".

Not all aspects of the course were appreciated, although many comments will help guide future improvements.

- "The grading system was vague. Directions are sometimes hard to understand".
- "Have mini-device development case studies".
- "A little more information on annotated slides and pitches".
- "It would have been cool to have some professors from management or economics give brief lectures, maybe even psychology [sic]".

Nearly all students commented on how they expect to use the skills, knowledge and mindset they learned in the future.

- “Overall this has been my favorite class so far and the one that I think I will pull the most from after I graduate”.
- “The course peaked my interest to explore other areas that I hadn’t through about before”.
- “I learned a lot of practical skills and ways of thinking that I know I will use later”.
- “I learned that business is much more complicated than I thought”.

5.2 *Post-Course Evaluations*

In Fall 2014, the same 15 seniors were now engaged in the first semester of our senior capstone design sequence. They were asked to reflect on the following four questions.

1. What were your main take-aways from product archaeology?
2. In what ways has product archaeology informed your view of how engineers function within a company?
3. Have you used product archaeology, or elements of it, in other classes or projects? How? Where?
4. Do you anticipate using product archaeology again? How?

Many students echoed similar comments above but now six months later.

- “I reflected back upon the company as a whole and the mission of the company”.
- “I have a greater awareness of how business works”.
- “. . . consider all facets of business and how they relate to one another”.
- “. . . seeing an over-reaching representation of the different considerations that go into making decisions”.
- “It is rare for a business decision to be made for technical reasons, and the Product Archaeology Canvas really helped bring this fact to light”.
- “Markets in other countries got me thinking about engineering in other countries”.
- “The product canvas was a really good teaching tool”.

Some students commented on the role an engineer plays within a business.

- “They showed me what part of the puzzle the engineer fits it”.
- “. . . realized that engineers play a smaller role in terms of how a company functions”.
- “Product Archaeology made me realize that engineers can really be involved in all activities associated with bringing a new, improved, and/or redesigned product to the market”.

- “Engineers, therefore, should have input into all of the company segments of the PAC, because increased cross-disciplinary functions leads to better communication, augmented understanding of product life cycles, and ultimately, product success”.

Students also are applying product archaeology to their senior design projects. 12 of 15 of our seniors said that they were actively using product archaeology as a way to drive forward their project.

- “Each aspect of a product’s life cycle reflects back upon its proposed value proposition”.
- “PA has helped our team identify where we need to perform more research”.
- “Our team is using it to guide our faculty panels, as well as our presentations”.
- “It is great to prepare for our presentations, because it gave us a good guide for how to move through the presentation”.
- “. . . acted as a good visualization of our thinking process”.

Some students also explained how they were using product archaeology in job interviews and hinted at how they might use it later in life.

- “I have used a version of it [as a] Student Engineering Consultant at the SBDC”.
- “It set me apart from other candidates when applying for jobs and maybe later being considered for promotions”.
- “. . . .so that I can go into job interviews and know what I am talking about”.

We expect to follow up with these students after they graduate to obtain more data on the impact of product archaeology.

5.3 Preliminary Industry Assessment

The goal of product archaeology is to mirror the complex decision making process that occurs within real businesses. Preliminary industry input has taken the form of unstructured interviews of nine industry leaders who are in a decision-making capacity that cuts across traditional business divisions (e.g. CEO, COO, Board President). This was to ensure that the views expressed would not be myopic (e.g. asking a Chief Financial Officer how decisions should be made may be too biased toward finance). The initial response of industry leaders has been very positive. All six agreed that engineers with product archaeology experience would be highly desirable and would be in a good position to innovate from within an existing business structure. Four indicated that engineers with product archaeology experience (intrapreneurship) would be more desirable as new employees than those with a pure entrepreneurial experience. Two said that product archaeology may be pedagogically useful in business schools and as a way to train new employees on how decisions are made within their company.

Some comments from these interviews:

- “I would say that all of the topics as a whole are appropriate. Depending on the specifics there would be priorities. Maybe weight some more than others”.
- “We use a number of metrics within each area to determine how we are doing. We track good and bad customer feedback. Compliance with federal regulations is huge for us so we track metrics for individuals as well as the organization. Finance is an easy metric”.
- “I might rename some things or add definitions that are more aligned with our vernacular”.
- “I could imagine using this within all departments within a company. Make them go through all areas except their own. And then only later let them look for innovations in their own area”.
- “Maybe this could be used as a training tool for new employees”.

A more formal study is on-going and will be reported in a future manuscript.

6 Limitations, Variations and Extended Applications

There are many limitations to the PAC that could lead to future work. First, more clear and measurable pedagogical goals will need to be developed. Second, the validation of the PAC with both industry and academic thought leaders should be continued. Third, I have made modest attempts to disseminate the canvas out to other academics. It is hoped that this paper can be a first step toward wider dissemination. Lastly, there are many possible extensions of the PAC framework. Although I cannot speculate on how the PAC framework will translate to all combinations of these variations, that is in fact the power of the framework – it can likely be adapted to many other situations both inside and outside academia. Below are some variations and thoughts that may be useful to those who wish to adopt the Product Archaeology Canvas.

6.1 The Canvas

The canvas itself can certainly be modified to suit the needs of a particular course, discipline or project. It was noted by several industry leaders that their names and way of combining (or splitting) divisions within a business. It would be simple to redraw and rename boxes on the canvas. The key is to keep value at the center of the canvas. As the canvas appears in Figure 1, all of the boxes are roughly the same size. Just as there is only so much space on a page, there is only so much time/effort allocation that a team can invest in each area. In reality, the allocation will not be the same size for a given project and so the sizes of the boxes could easily be changed. In reallocating box size, an instructor (or project director) might pre-set the sizes of boxes to indicate the time/effort allocation. Doing so would visually communicate the relative importance of various topics. An alternative would be to allow the project group to modify the canvas as a way to begin thinking about the execution of a project. The result would be a shared vision for how the group will allocate their attention. To provide a more moderate level of control, a group leader may put restrictions that no box can grow beyond a certain size and no box can shrink to zero. The PAC might also become dynamic as a project enters and exists stages of development. For example,

at the onset of a project it may be that stakeholders, finance and marketing occupy the most real-estate. In the middle of a project it might be operations and technical design, and toward the end it might be sales, manufacturing and distribution. The PAC could be used as a diagnostic tool while the project is on-going to determine if the actual allocation of attention and importance matches the group's initial allocation. If it is not, the PAC could be used to either rebalance efforts or trigger a redrawing of the canvas. Lastly, it is often the case that an engineer will work on several projects at once. Having one PAC for each project could help with task switching.

6.2 *Student Learning*

From the perspective of a student, there are modifications that can be made that make the PAC more powerful. Practically, students can use the PAC to self-vet project ideas. Rather than the engineering design (Pugh) matrix approach, which typically leans heavily on technical considerations, the PAC can be used to provide a more holistic assessment. I am currently testing this approach with my senior design capstone team. Students can use the PAC to organize their presentations. In fact, several groups used Prezi⁵¹, with the PAC as their base image, to drive forward their final presentations. In-class presentations also allow different groups to see alternative pathways toward generating value. There is no one-size-fits-all approach to value. The backward archaeology phase could also be used to drive forward a case study, using the PAC to deconstruct why a product succeeded or failed.

As a developmental tool the PAC can highlight that real world decisions are complex and multi-dimensional. This is critical for an entry level engineer, as our graduates who are entirely technically focused will quickly become frustrated in an industry setting. It can also help those engineers who will move into a managerial positions. The canvas could also be used to visualize how topics are being connected together. The assignment would be to rearrange the size and location of boxes to more accurately reflect the flow of a project and how decisions are being made. The PAC also has many opportunities to discuss professional development. In BMEG 408 there were many opportunities for students to exercise good professional skills that include writing memos, making and presenting annotated slides, conducting meetings, and interacting with real companies. The combination of backward and forward archaeology can also show that engineers are part of a larger value chain. And that technical considerations weave in and out of this chain at different times in the development of a product. In fact, it could also be used to highlight that different types of products require technical development at different phases. Lastly, the PAC can dismiss the myth (in a way that the BMC does not) that innovation is not only the domain of freewheeling 20-somethings in hip urban areas working for small start-up companies⁵². Instead they experience how large corporations can innovate through both incremental and radical changes to their product portfolio.

6.3 *Faculty and Curricular Considerations*

This paper outlines a course that allows the integration of entrepreneurial topics before the senior capstone. But the PAC could be integrated into senior design, put earlier in the curriculum, be

offered as an interdisciplinary elective or serve as a thread that appears through a curriculum. As the PAC does not require a deep background in math and science, the framework could in principle be used very early in the curriculum. The PAC can support many learning objectives that will be associated with individual boxes, but because it is conducted on a real device, the canvas naturally creates a way to bind together topics. In addition it will quite naturally touch upon nearly all soft skills required by ABET^{53,54}. There are several other lenses through which this same approach may focus student attention. The first is the three-legged stool of sustainability – economic, social and environmental. Another would be to understand organizational change models^{55,56,57}. Yet another is the integration of the liberal arts into engineering to form a T-shaped engineer⁵⁸. Lastly the PAC is, for the most part, methodologically neutral. It could just as easily be driven by lectures, problem/project based or other inductive methods, a flipped classroom or could form the basis for a MOOC.

6.4 *Outside of Engineering and Academia*

There are other possible applications for the PAC outside of traditional curricular offerings, outside of engineering, and perhaps even outside of academia. It is possible for bootcamps, pitch competitions and other immersive experiences to be driven forward by the PAC. Doing so would naturally drive the formation of interdisciplinary teams and a more thorough analysis of a business idea. Because nearly any artifact could be used, there is great potential for company involvement, with students playing a technical consulting role⁵⁹. Likewise, intrapreneurship could be introduced to non-engineers. For example, for those students in marketing, The PAC could be used largely unchanged because the general objective remains the same - to demonstrate the complex value-driven inner workings of an existing business. The key is to go through each box other than your own discipline in the backward archaeology pass. Only then are many value propositions generated from your own domain. Business schools might also use the PAC as a way to introduce leadership and what it means to make hard decisions in the face of both internal and external uncertainty.

Outside of academia, the the PAC could also be useful as a consulting framework both to gather information (backward archaeology to diagnose problems) and for making recommendations (forward archaeology). The PAC can be used to quickly identify areas of non-alignment in an existing company. An addition to the PAC might be questions and metrics that are measured (similar to the balanced score card⁶⁰) within each box. In this sense it can be used as a diagnostic tool or as a way to quickly vet a new idea for alignment. This is similar to the Will It Fly method⁶¹. Within a corporation, the PAC might also be useful as a training tool for new employees and to communicate how decisions are being made. In addition it may serve as a framework for how employees should pitch their ideas to middle and upper management. Lastly, the PAC might be modified for the developing world and non-profit organizations.

7 **Conclusion**

The goal of the Product Archaeology Canvas is to provide the intreprenuer with a robust but flexible unifying framework for generating ideas, vetting those ideas, guiding execution, monitoring

progress and diagnosing problems. This paper has focused on the pedagogical implications of using the PAC to teach engineers to think like entrepreneurs. The short-term value of teaching with the PAC is to highlight how decisions are made in the complex and rapidly changing environment within a company. The long-term value is to develop habits of mind and action that will enable them to make impactful contributions throughout their careers.

8 Acknowledgements

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APPENDIX A - Select Topics

It is not possible in a single course to cover all elements of the PAC in detail. What is offered below are some of the topics (with associated resources and readings). The list is far from exhaustive and is not meant to be prescriptive. Most of the topics can be found in the following sources:

- *Business Model Generation*^{21,25}
- *The Startup Owner's Manual*⁴⁹
- *Engineering Project Management*⁶²
- *Managing Engineering and Technology*⁶³
- *Principles of Marketing*⁶⁴
- *Technology Entrepreneurship*⁶⁵
- *Technology Ventures*³
- *The Innovator's DNA*⁴⁷
- *The Fifth Discipline*⁶⁶
- *Will It Fly*⁶¹
- *QuickMBA* (online)⁶⁷

There are also some excellent sources for frameworks and activities:

- *Gamestorming*³⁵
- *The Innovator's Toolkit*³⁶
- *Thinkertoys*⁴⁰
- *Serious Creativity*³³

Value Proposition

- Business Values and Mission Statements
- Business Strategies and Tactics
- Product Portfolios
- Innovation Value Chain
- Value as being a ratio of benefit/cost – where both benefit and cost are broadly defined
- Business alignment – McKinsey 7S framework
- Incremental vs. radical value propositions

Marketing

- Customer Life Time Value
- Market Research (doing your own vs. Databases)
- Competitor Analysis
- 4 Ps of Marketing
- Perception Maps
- Marketing Channels
- Diffusion of Innovations
- Marketing Psychology (e.g. Adoption Pathway)
- Brand Creation and Maintenance

Stakeholders and Customers

- Stakeholder Analysis
- Stakeholder Analysis Maps
- Methods of learning about stakeholders (e.g. interviews, observations, surveys)
- Market Segmentation
- Knowing Your Customer vs. Ignoring Your Customer

Sales and Distribution

- Sales Models: One-time or repeat purchase, Bait and Hook, Freemium model
- Sales force training and recruiting
- Bundled services
- Sales forecasting
- Distribution channels
- Distribution Chain (with distributors and vendors)
- Packaging

Legal and Regulatory

- Business formation and dissolving
- Intellectual Property (e.g. patents, copyrights, trademarks)
- Government organizations (EPA, OSHA, HIPAA, FDA)
- Health Care Reimbursement
- Industry Standards (e.g. ISO, ASME)

Finance

- Budget Creation (*e.g.* Fixed and Variable Costs)
- Forecasting
- Accounting
- Growth-share Matrix
- Economies of Scale
- The Long Tail

Operations

- Business structures and organizations (*e.g.* flat vs hierarchical)
- Jobs to be Done Framework
- Manufacturing and Assembly
- Product Life Cycles (Growth and Decay)
- Porter's 5 Forces
- SWOT Analysis
- Supply Chain Management (*e.g.* Location, Production, Inventory, Transportation)
- The Bullwhip effect

Resources

- Human Resources
- Training and Professional Development
- Strategic Partnerships
- Investments

APPENDIX B - Surveys

All surveys and procedures were approved by the Bucknell University Institutional Review Board. All were embedded within qualtrics and accompanied by an email.

Past Students

The Product Archaeology Canvas (PAC) that we used in BMEG 408 has received attention from other engineering and business faculty members, both nationally and internationally. One of the most common questions I have receive is about the student perspective of using the PAC. While I have so far relied on my observations and course evaluations, I would like to gain more information on your perspective now that you are in senior design.

What I would ask is that you take about 15 minutes to fill out the attached survey (there are four questions to answer). This is voluntary but your feedback is important not only to make the PAC better here at Bucknell but for others who may use it in the future.

My two overriding goals in introducing the PAC were to: 1) provide a more holistic picture of how decisions are made within a company and 2) show how and where engineers can provide value to a company. Both are aimed at educating engineers (You!) who can add to the value of their organization (whether that might be research, industry, government, medicine, non-profit, law or finance). With that as a context, please respond to the following questions.

1. What were your main take-aways from the PAC?
2. In what ways have the PAC informed your view of how engineers functions within a company?
3. Have you used the PAC, or elements of it, in other classes or projects? How? Where?
4. Do you anticipate using the PAC again?

Industry

Hello NAME,

I am contacting you to ask for your participation in a 15 minute (4 questions) survey of a pedagogical tool being created at Bucknell University. The tool is the Product Archaeology Canvas (PAC) pictured below and has been used in some Bucknell classes. The goal of the PAC is to provide engineers with an understanding of how real and complex business decisions are made. In a typical course the PAC is used to deconstruct the business decisions that were made to bring an existing product to market. Student move through each box on the canvas and collect as much publicly available information as possible on their assigned device. For example, within the customer/stakeholder box students explore the customer viewpoint through customer perception maps, empathy maps, survey methods, and the stakeholder perspective through techniques such as stakeholder analysis and influence maps. The end purpose is for the students to gain a more holistic picture of the many decisions involved in bringing a product to market, and how these decisions must attempt to align the value to the customer and the value to the company.

The canvas was created primarily from academic sources (business journal articles, case studies and text books). For that reason, validation from real industry leaders is critical. As you answer the questions, I would ask that you keep in mind internal proposals you have received and what PAC elements were important in convincing you that an idea was (or was not) feasible and complete.

1. Are there elements of the PAC that you weight more heavily in making decisions?
2. Are there elements of a proposal that you consider that are not part of the PAC (e.g. the team from which the proposal originated)?
3. What metrics does your company use to measure success? Do these measures align with particular elements of the PAC?
4. How might the canvas (perhaps modified) help communicate to your employees how value is being assessed? Might the PAC be used during orientation of new employees?

5. May I contact you to clarify any of the responses above? (YES/NO)
6. Although I will not share any identifying information, would you like to be acknowledged in the final paper? (YES/NO)
7. Would you like a copy of the paper when it is published? (YES/NO)

If you would like more information about the PAC or how it is used in the classroom, please contact me at jvt002@bucknell.edu.

Best Regards,
Joe Tranquillo
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