Bringing the University to the Workplace: Targeted Short Course Development

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Abstract

This article explores aspects of strategy for the development of a scientific or engineering educational product to meet a specific competency gap at the request of commercial or industrial customers. This goal may present several challenges to the University, especially where it may deviate from traditional educational praxis. The economic and logistic needs of external customers may require a highly condensed course which precludes time-intensive learning activities often relied upon in a more conventional educational context, and competing learning objectives may exist between the technical perspective of the students in the course (e.g., design engineers or analysts) and those with a more business-oriented viewpoint (e.g., managers) who have authorized the financing of the course. A successful educational outcome should satisfy the spectrum of expectations. This requires a robust understanding of the needs of the company as well as the individual students, so University educators should be responsive to integrate this into the content, organization, and delivery of high-level technical short courses.

1. Introduction

Much research has been undertaken to understand and enhance one primary mission of the University as an institution: the education of students. The bulk of this work has focused on an interaction where students go to the University in its own context, whether that be a physical presence on a campus or through distance learning programs. In each case, the tone of this interaction is largely set by the culture of the University, comprised of values, expectations, and styles of communicating. This approach may benefit many students, who will grow and flourish in the University context; however, the inherent research mission of the University cultivates many assets which offer value to quite a range of customers. The task of transferring the intellectual and technological products to these customers is far from simple, and in many cases may require the University to adapt to the culture of the end-user or users. Nowhere is this idea more applicable than in the high-level education of people, where the product is actually human development. If this endeavor is undertaken in a more constrained context than is typically expected in a graduate program, for instance, then the University should understand how to tailor the curriculum to meet the unique objectives of the context.

The engineering workplace is undergoing rapid change which requires practicing engineers to engage in human resource development in order to design and develop successful products. The change is being driven by the introduction of new technologies allowing for increasingly complexity in engineering designs. Adaptation to new engineering methodologies is now a crucial skill for practicing engineers. In university settings, there is often discussion regarding lifelong learning [1], [2]. However, as products become increasingly intricate, informal learning within the workplace can no longer provide practicing engineers the required support to take advantage of new or complicated engineering methodologies. Formal learning opportunities, which are offered within the highly structured educational system, do provide the technical
knowledge necessary but are not designed for practicing engineers who are primarily focused on work responsibilities. However, there are also nonformal educational opportunities which are offered outside of the formal framework. In this category, programs are organized and systematic and target specific groups and their unique learning needs [3]. It is within this nonformal space that universities can expand outside of the strict formal structures of the institution and engage practicing engineers with specific technical knowledge that is required to adapt to the rapidly evolving engineering workplace.

This article presents a case study of a new interaction between a University and an industrial company, which approached the first author for assistance to understand the physics and design principles of a new product line: hydraulic anti-vibration products. Several aspects of this interaction warrant some discussion. The nature of hydraulic anti-vibration products are that the desirable dynamic properties result from rather complex interactions between design features, and it is not clear how one would have any command over producing those desirable features without a robust understanding of the underlying physics, as well as some experience in handling the optimization of parameters. Since a quick fix was therefore off the table, the decision was made early on to handle the knowledge transfer in the form of a short course, to be given to engineers, engineering managers, and engineering salespeople on site at the company’s facility. This decision produced an opportunity to engage in the human resource development through repackaged graduate-level education delivered to individuals who may have found more traditional graduate programs within the formal educational structure inaccessible, carrying forward the University’s missions of engagement and inclusivity.

2. Constraints for the Short Course

2.1 Stakeholders

The success of this short course can be defined in terms of achieving the values of several stakeholders. First, the students who took the class had a vested interest in learning the new material so as to stay updated and capable in their careers. Some of the engineers who took the class would go on to use the information directly as they worked to design and analyze hydraulic anti-vibration products. Others worked in tangential fields like material science and were taking the class to broaden their knowledge base. To meet the needs of these individuals required a meaningful packaging and delivery of the new concepts and some degree of integration into skill. The second category of stakeholders is the engineering managers, who had committed resources to make the short course a reality. The business case for this class required that new capabilities be achieved, so that the new product line could be run successfully by the company’s existing employees. Success in this case required achieving competency in hydraulic bushing design. Finally, although our principal aim in this case was to serve these two customers, the University itself had a stake in the carrying forward of its educational mission which includes creating and discovering knowledge to improve the well-being of communities and fostering a culture of engagement [4].
Care was taken to meet all of these objectives in the manner in which the course development occurred in the two months or so leading up to the event. The course was split into three sections, the first being focused on basic, direct concepts. This laid the necessary theoretical foundation but would perhaps not appear directly relevant to the higher-level goals. The second section integrated these concepts into system principles which more directly relate to the properties of the hydraulic devices. The third section took a further step to develop how these component level properties affect larger systems. This served to solidify the importance and applicability of the prior two sections, and provided an opportunity for the students to engage with the analytical and computational materials previously discussed to engineer solutions to actual vibration problems using the hydraulic anti-vibration device as a solution.

2.2 Compressed Nature of the Short Course

Hydraulic anti-vibration products employ tuned interactions between relatively complex phenomena to achieve their desirable properties, and thus a conceptual understanding of many ideas is needed to efficiently design such a device. In a traditional university setting, a laboratory oriented graduate course could be developed on the topic, including content from characterization of existing components to the design of new ones, based on a significant analytical and computational grasp of the underlying physics. However, since the students of the course were taking time away from their regular job responsibilities to engage with this program, an entire semester was not feasible. Appropriate condensation of the material to a short form was necessary so that the program could be completed in less than a week. Since time could not be taken for lengthy demonstrations, examples and illustrations were designed such that they were exceedingly relevant for this audience. The course included in-class problem solving sessions with structured examples, and the overall course outline was focused on the technical knowledge needed by these engineers. Although some nuanced elements of hydraulic anti-vibration devices had to be set aside as a result of this focused design, the material that was included was specifically designed to support these learners to improve their engineering practice.

2.3 Education and Training

The goal of this program was to educate the students on the covered topics and not simply provide a training on how to execute a design algorithm. Education speaks to an increase in understanding of concepts, while training is specific to acquiring a set of skills. This is an important distinction and one that is becoming more relevant as engineering techniques advance. Historically, general knowledge is marketable throughout the workplace and is acquired in formal educational settings. Engineering students that are entering the workplace acquire this general knowledge during their years at university. In contrast, training addresses organization-specific learning programs such as software training [5]. However, as the complexity of engineering methodologies increases, it is necessary to discuss underlying principles within the context of organization-specific learning programs. This confluence of education and training is where a university can blend more traditional academic materials with practical applications outside of the constraints of the formal education system. In order for practicing engineers to
execute design algorithms or use software tools, a broad understanding of the underlying engineering principles is now required. The university can expand its reach and engage practicing engineers by using nonformal educational formats which are designed specifically for engineers in the workplace.

3. Hydraulic Anti-Vibration Concepts

3.1 Overview of Hydraulic Anti-Vibration Technology

The modern hydraulic anti-vibration product has many variants, but the general working principle is shared amongst them. [6] The device is an interfacial element, acting in between two objects where a reduction of transmitted vibration is desired. Typically made from metal and elastomeric materials, these devices have internal fluid chambers which are filled with a viscous fluid, typically some kind of glycol mixture or oil, to prevent freezing. As relative motion occurs between the two objects, the fluid is pumped from one chamber to the other, traveling through flow paths and obstacles. Since there are significant energy losses as the viscous fluid moves through these features, a high degree of energy dissipation, or damping, can be achieved, compared with similar elastomeric devices that lack the fluid system. Furthermore, since the fluid system is, to some degree, a parallel addition to the solid structure, it can be designed to create highly tuned dynamic properties. The effect is that the bushing or mount can behave as a very compliant joint at low frequencies, which is good for vibration isolation, and provide extremely high damping at a narrow band of frequencies, which can be tuned to attenuate a particular frequency of transmitted vibration.

Controlling the dynamic properties of hydraulic mounts or bushings can be quite challenging since these properties emerge as the result of interactions between design features, they very likely include significant nonlinearity, and because they often depend on how the device is loaded [7], [8], [9], [10]. Many studies have been undertaken to analyze the features of hydraulic mounts and bushings in detail, but these generally focus on the more advanced or nuanced features. The basic interactions may be understood as an extension of undergraduate system dynamics with the inclusion of some nonlinear elements.

3.2 Concept Categories

The concepts needed to understand the functionality and design of hydraulic bushings may be classified into two categories, direct concepts, which are directly apparent in a standalone fashion, and emergent concepts, which are not standalone and result from some combination of direct concepts [11], [12]. In the case of hydraulic anti-vibration products, the direct concepts are physical principles, as outlined in the first box of Figure 1. These provide the physical basis for the lumped model depicted in Figure 2. These component properties, listed in the second box in Figure 1, are also direct concepts, but deal with relationships between quantities for which physical intuition may be uncommon, such as volume flow rate or the effective volume of an accumulator. The intermediate step was designed to provide a bridge between the well-known physical principles and the more nuanced context of a hydraulic
bushing. The third step of the organization is the system properties, not directly accessible from design features of the device. Only through a proper understanding of component properties and how they interact, can the system properties be understood. These are emergent concepts.

![Diagram](image1)

**Figure 1.** Multi-layer concept structure used for the first two sections of the course content.

![Diagram](image2)

**Figure 2.** Lumped-parameter model of a hydraulic bushing

### 3.3 Implementing the Concepts into the Course Structure

The course design was guided by the end goal of providing students an understanding of the emergent concepts, because these concepts inform whether a design meets the specification or not. The **tune frequency** is given as an example of such an end-goal parameter in Figure 3, showing how it is dependent on the component properties of **fluid compliance** and **fluid inertance**. These are themselves dependent on the direct concepts of **elasticity** and **fluid-structure interaction** for compliance, and **inertia** and **effective areas** for inertance. This structure therefore
provides a road map for instruction. The physical principles are reviewed first, providing the foundation for the direct concepts, whose interactions lead to the emergent concepts that are the goal of the course. This process was done in the first two sections of the course and repeated for even higher-level concepts in the third section.

This method seemed to work well in bringing the students along from familiar ideas to unfamiliar, and from tractable concepts to the obscure and abstract. Structuring the course in terms of these necessary concepts also served to identify which concepts could be cut in order to meet the condensed format of the course. For instance, nonlinear phenomena are common in hydraulic anti-vibration products, but these would be emergent concepts relying on both the component and system properties. As such, it was decided that a robust treatment of nonlinear properties of hydraulic bushings and mounts would be a fourth category and should therefore be given in a follow-on course.

![Figure 3. Direct and emergent concept dependencies](image)

4. Expressing Knowledge

4.1 Contextualizing Concepts

Conceptual growth is aided by contextualization [13], so the particularly stringent time constraints placed upon the short course require extensive use of contextualization in introducing new concepts. Additionally, adult students learn in order to cope more satisfyingly with real life tasks and problems [14]. From the instructor’s perspective, the most fundamental nature of most of the direct and emergent concepts would be an equation, or a plotted mathematical relationship. However, this is also an abstract conceptualization, and may be harder to communicate in the absence of a visible or tactile connection to the application, which is what drove the need for the course in the first place. For this reason, an introduction was given for each feature, and how it physically results from structural or fluid motion in the device.

Since an example part had already been selected and the company’s team had already worked on this device, a digital version of that part was constructed using the finite element method. Each feature was isolated and demonstrated with animated visualizations of the finite element model, as illustrated in Figure 4. This facilitated the contextualization of the abstract
concepts, like effective pumping area, not only in terms of a physical part, but also in terms of the community values, which was to develop a mastery over the features of this particular part.

![Finite element model visualization of a sample device for characterization and contextualization of the component property concepts.](image)

**Figure 4.** Finite element model visualization of a sample device for characterization and contextualization of the component property concepts.

### 4.2 Distributed Understanding

Since the goal of this short course was to equip a team of engineers to design and manufacture hydraulic bushings rather than to teach individuals arbitrary facts about the bushings, it was important to ensure that a distributed understanding was developed [13], [15]. The students represented a range of roles and experience levels and had many different observable dynamics as they interacted. To engage these group dynamics, breaks were included between lectures to provide an opportunity for informal discussions amongst the team and for collectively working through problems. Some of the engineers had experience with mechanics and readily took to the solutions of the problems, while others’ backgrounds were from other fields. This format of group discussion and problem solving enabled them to work together, contributing each from his or her experience to bring the rest of the team up to speed. At one point, one member of the team who had apparently previously taught physics at a local college got up and essentially delivered an extemporaneous lecture covering the solution method for the problem and why it was appropriate. This kind of dynamic indicates a successful interaction from the authors’ perspective, because the internal dynamics of the group can and will continue on even after the course is over, fostering continued development of the distributed understanding. If, after the instructors have left, the students can continue to process and learn the information which was presented in perhaps insufficient time to be fully retained, then the conceptual growth process is not dependent on the instructor’s presence and real progress has occurred.

### 4.3 Identification and Adaptation to Concept Difficulty
The issue of concept difficulty may be challenging for an instructor to anticipate, since, as some degree of expert, the familiarity of the concept may mask the difficulty that he or she had in learning it at first. Experts not only possess greater knowledge, but organize, access, and apply this knowledge very differently than novices [16]. Nevertheless, some guidance is available to understand concept difficulty. Apparently, concepts are more difficult to learn when (1) they are not directly observable and (2) when a macroscopic pattern emerges from unobservable microscopic phenomena [11], [12]. Both of these issues exist in the context of hydraulic anti-vibration products. In this case, the instructors tried to resolve the concept difficulty through the breaking down of emergent concepts into their constituent direct concepts. The remaining challenge was the ongoing assessment of how the individual students were perceiving conceptual difficulty so as to be able to adapt to it, to make sure that a robust understanding has been achieved before moving on to emergent concepts which depend on it. In particular, observing the team’s internal discussions and processes working through solving the problems was most helpful to identify any unforeseen concept difficulties, as well as offering the informal opportunity to provide additional help.

5. Reception and Response

5.1 Evaluations and Stakeholder Metrics

Since the students were not beholden to the instructors for a grade, no formal evaluation of the students was undertaken. However, a short evaluation form for the course and instructors was given to the students at the end of the course, including five questions:

(1) What do you feel were the strengths and weaknesses of these instructors?

(2) How do you feel the instructors could improve their teaching of this course?

(3) Please rank the instructors from 1 (low) to 5 (high) on the following aspects:
   a. Instructors well prepared
   b. Encouraged independent thinking
   c. Learned greatly from instructor
   d. Interested in helping participants
   e. Overall rating

(4) How do you feel the course could be improved?

(5) Other comments

In general, these received overwhelmingly positive responses. The students’ perspective was that they had learned the material, that their capabilities had expanded, and that the course was well-
designed to educate them given the time constraints. However, 75% of the evaluations came back with comments suggesting that more time and more examples would have improved the course. This feedback seems to indicate that the learning objectives of the students were reached, although more of what was provided would have been helpful.

At this point, a tension arises with a manager’s metric for success, which would be the maximum improvement in capability for the minimum cost. Increasing the daily content was likely infeasible, as the intensity of the course was already substantial, so the only other option would have been to extend the length to beyond one week of business days. This would have inflated the cost, and so it’s not clear that a longer course would have been justified from this perspective. Nevertheless, after discussing what was learned with the team, the managers indicated that they were pleased with the course.

Finally, the University’s perspective on a successful interaction can be measured in terms of whether education has occurred. In other words, have the instructors successfully engaged with the students in their own context and contributed to their conceptual growth? In simple terms, this was verified by a final exercise, wherein a vehicle system with a vibration problem was presented to the students, and they needed to use a software tool the instructors provided to design a hydraulic anti-vibration mount to solve this problem. At the start of the course, the students lacked the conceptual knowledge and skills to accomplish this task, but upon receiving the problem on the final day, they were able to choose the minimum number of mounts which were required and their locations, and what design parameters were necessary to treat the vibration problem. Furthermore, since both the students and managers positively indicated satisfaction with the short course, the authors consider this course to have been successful.

5.2 Improvements and Future Short Courses

Since this course was a positive experience for both instructors and students, and since it seems to have filled a niche which was not readily available, the idea of improving and expanding the University’s offerings of this type of course should be investigated. In particular, the short course seems to fit into a gap where high-level research can be packaged into an educational program and conveyed to customers who may not have the time to participate in more traditional graduate education. Academic research efforts are constantly developing such material, and while it may be some time before some of it has matured to the level where industry is requesting it, the ability to package research expertise into short courses may facilitate that technology transfer and shorten the lag. Many questions exist about the best way to achieve this goal, and clearly short courses are only one possible way. Nevertheless, the ability to develop such programs efficiently and potentially on-demand would doubtlessly enhance the University’s mission.

The addition of alternative credentialing, such as certificates and badging, are evidence the universities are interested in bridging the gap between formal education structure and more nonformal environments [17]. These programs must account for the needs of adult learners. Adult learners, in general, are self-directed, have highly developed prior experiences, learn in
order to cope more satisfyingly with real-life problems, and are performance centered [14],[18]. In addition in considering the characteristics of the learner, training design must also be considered when engaging practicing engineers [19], [9]. Designing programs which situate the learners in their own work environments not only alleviates the burden of travel, but also engages the learners in an authentic learning environment by engaging learners in their own work environment [19].

If this hydraulic anti-vibration product course is to be used as a foundation on which to improve for future short courses, several improvements should be made. First, since the time and energy constraints for this course were so limited, the structure of the course was fairly rigidly controlled. The students may have benefitted from a more flexible delivery, especially one with more interactive engagement. Secondly, very little attempt was made in the way of evaluation. While this probably didn’t hinder this course, it does seem like somewhat of a loss, since that data could have been used to assess the nature of the course and improve it for future iterations or similar endeavors, especially were a robust framework of evaluation to be used [21]. Finally, this course had significant potential to connect with other follow-on courses, seminars, or other educational materials reaching topics which couldn’t be fit into the condensed time allotment. There is a certain level of momentum which was produced by the short course. Because the additional materials were not already in place, it will be more difficult to restart that engagement than if it were seamlessly connected.

6. Conclusion

This article discussed a recent case study of a short course offered by a University to an industrial company at their own location, with a focus on how the pursuit of conceptual understanding affected the course structure. The constraints of a short course, especially as compared to traditional graduate courses, played a significant role in what content was included and how it was packaged. Some of the concepts involved with hydraulic anti-vibration products were presented with some discussion of how the direct and emergent concepts fit into the structure. In delivering the course, concepts were expressed through contextualization to the company’s application, and a distributed understanding of the concepts was sought with cognizance to the difficulty that different members of the team would experience in understanding the new material. Finally, the positive reception of the company to the course and feedback gave some insights as to the utility of the short course model, as well as some improvements which could be made in developing more courses of a similar type. This short course was a positive experience for all stakeholders and reflects an opportunity for engagement in the workplace.

References


