ADVISING STUDENTS IN TECHNICAL PROJECTS — RECOGNIZING PROBLEM SCENARIOS

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ABSTRACT

In this paper, we consider the advisor's role during the technical work and the thesis preparation for a student in the final phase of a course of study in an engineering education. We initially claim that there is a marked difference between the learning that takes place in regular course work and the learning ensuing from project work. Concrete differences include that

- unlike the a-priori fixed curriculum of regular courses, an important aspect of a project is to define and scientifically formulate the problem itself, in which the student is to be engaged.
- projects are carried out individually or in very small groups. For an interesting project, the precise outcome cannot be known in advance.
- The flexible and individual nature of each project requires that time must be carefully divided and managed between defining the problem, seeking information, implementing solutions and presenting results.

While students work hard during projects and advisors will do their best to support the students' activities, it is not uncommon that a student fails to meet either his or her own expectations and/or those of the advisor. Occasionally, this is true also of students who perform brilliantly in regular courses. The goal of this paper is to relate the authors' experiences and investigations into the project advisory process and to provide recommendations for other engineering educators.

After an initial discussion of a typical engineering project advisory process, we review a number of representative projects (abstracted and anonymized) and analyze conditions under which a failure to meet or match expectations is likely to arise. This leads us to a small number of scenarios, where a student is likely to under-perform.

Common to these scenarios is a lack of balance between the necessary activities in an engineering project. As our main contribution, we investigate and categorize these imbalances leading to the aforementioned scenarios. Finally, we distill suggestions for best project advisory practices.

KEYWORDS

Assessment, Project-Based Learning, Advisory Process, Design-Implement Experience, Active Learning, Standards: 5, 7, 8, 11

1 INTRODUCTION

The past decade has seen the introduction of numerous disruptive technologies based on Internet commerce, which have created new ways of supplying consumers with information based products and rendered old business models obsolete. It is now increasingly difficult to imagine a brick and mortar store based business model for selling any product whose core is information. Yet, universities are, in a sense, precisely brick and mortar stores for selling an information based product. While it is true that inroads made in online education have impacted universities, this effect is arguably much less than, say, the effect of online publishing on the book business (Cook, 2011).

This might seem surprising since online education allows a few teachers, the absolute elite within their field, to teach thousands of students. Put differently, teaching a regular, curriculum based course, appears to scale when taken online (Kellogg, 2011), although drop-out rates are high and innovative thinking is required when it comes to assessment (Conole, 2013). Arguably, these changes make project based learning increasingly important. Regular courses impart engineering students with problem solving tools within a fixed framework. Project based learning in contrast, engages students in solving actual problems: from inception, through solution and final dissemination. In most cases, different students do different projects, and each project has its own pitfalls, idiosyncrasies and measures of success. The professor in each case assumes the role of a coach, mentor, and, of course, advisor, which is the term we use below.

Clearly, this kind of one-on-one intensive teaching does not scale well, since even the most dedicated educator can only provide individual attention to a limited number of different projects. One might argue that if it does not scale, we should do it less. That is not our position. Conversely, we feel that a defining property of project based learning is that it fosters creative, independent thinking. It is something the students do a lot towards the end of their studies and, conceivably, one of the saving graces of an education at a physical university.

While project based learning is definitely important, project based teaching is challenging for the educator. A part of the reason seems to be the Anna Karenina principle (Diamond, 1997) which we adapt as follows: all successful projects are more or less similar, and all unsuccessful projects are more or less dissimilar. Put differently, many things need to go right for a student to produce a successful project – one that meets the expectations of both student and advisor. A serious flaw in any one of these things, results in a mismatch of expectations, a lowered student grade and disappointment for the student, advisor and external examiner alike.

1.1 *Overview*

In Section 2, after an initial review of background ideas, we discuss the learning objectives of an engineering education project and how projects (especially final projects) are advised (in particular research groups) at the Technical University of Denmark and at the University of Toronto. With an understanding of the process in hand, we revisit a number of concrete projects in anonymized form in Section 3. In selecting our data, we restrict ourselves to projects where expectations were *not* met. Subsequently, we analyze these projects and categorize them according to which problem caused the failure to meet expectations in Section 4. From this categorization, we finally distill some advice for the project advisor in Section 5 and suggest directions for future work in Section 6.

2 BACKGROUND

The aim of this paper is to leverage learning assessment for the improvement of project based teaching. The goal of assessment is to measure learning outcome - the degree to which learning objectives have been reached (Gray, 2007). We surmise that advisors generally have expectations beforehand regarding the outcome of a project. Now, if the actual assessment at the end of a project reveals that the objectives have been reached to a lesser degree than expected, there is an unfortunate “learning deficit”. In this paper, our data is distilled into eight representative projects where we have observed such a learning deficit. We hope that by analyzing and categorizing these projects, we might ultimately arrive at some advice as to how to improve as an advisor so as to reduce the learning deficit wherever possible. Thus, this paper relates to Learning assessment (CDIO Standard 11, see Crawley, 2007, Appendix B). Specifically, we use the assessment of projects past in an effort to improve projects future.

Several other CDIO standards are also pertinent. A project is a *design-implement experience* (Standard 5) and an *integrated learning experience* (Standard 7) as well as an example of *active learning* (Standard 8). These standards describe how the project is embedded in the engineering education. From the student’s point of view, it is, also, interesting to consider what the learning objectives are, and how they relate to project work.

2.1 The Learning Objectives of a Project

If we look at the generic learning objectives for the M.Sc.Eng. thesis as outlined in (DTU’s Study Handbook, 2013/2014) the master project has a set of “overarching” objectives which map reasonably well to the following elements of the CDIO Syllabus (Crawley, 2007, Appendix A).

1 Disciplinary Knowledge and Reasoning
2.1 Analytic Reasoning and Problem Solving
2.2.2 Survey of Print and Electronic Literature
2.3 System Thinking
3.2.3 Written communication,
3.2.6 Oral Presentation
2.4.2 Perseverance, Urgency and Will to Deliver, Resourcefulness and Flexibility
4.4.2 The Design Process Phasing and Approaches
4.4.3 Utilization of Knowledge in Design

In most cases, experimental work (under 2.2) and societal issues (under 2.5) are also objectives. While this is specifically for the M.Sc.Eng. programs at DTU (the first author’s workplace), the objectives are similar at the University of Toronto (the second author’s workplace). For B.Eng. and B.Sc.Eng. projects at both institutions, we expect less. In particular, we do not expect quite the same overview of literature. In any case, these differences are not important in this context, since the advisor will always adjust his or her expectations according to both the individual level as well as the study program of the student. With this in place, we need to consider how students are advised during the project.

2.2 The Project Advisory Process

At the Section for Image Analysis and Computer Graphics in the Department of Applied Mathematics and Computer Science at the Technical University of Denmark we advise almost all project students according to the paradigm described in Paulsen et al. (2011). According to this paradigm, students must attend the weekly sessions of an advisory group.

Generally, there are between five and ten students in such a group and one or two advisors attend the meetings which last about an hour. During that hour, the advisor discusses each student's (or sub-group's) project based on a report of one or two pages that the advisors have read beforehand. A benefit of the report is that by writing it, the student obtains a lot of images, bibliographical references, tables, and other material which makes the composition of the final project report much easier. It also ensures that the report assessment is *formative* (Gray, 2007) to a very high degree. During the first sessions there is a strong emphasis on the motivation for the project. Moreover, during the first month, the learning outcome must be fixed (DTU's Study Handbook, 2013/2014). During the last sessions there is a corresponding emphasis on finishing the report and how to present the project at the oral defense.

Project based learning as exemplified in this paper at the University of Toronto, typically takes one of two forms. A one-on-one supervisory relationship for MSc projects or a class of 5-10 final year BSc students (sometimes in groups of 2-3) working on projects with a common underlying theme. All projects are equally likely to be proposed by the supervisor or student, and refined together to a scope that is challenging, yet feasible within the time allotted for the project (typically one to two semesters). The students then interact with the supervisor on a one-on-one basis or with peers in a classroom setting. Intermediate milestones, where students are evaluated on their ongoing progress are often set to manage expectations.

3 PROJECT EXAMPLES

In the following, we present a number of examples of projects where the end result deviated disappointingly from the expected outcome. We use the student grade as a measure of "result" and "expected outcome", since grades reflect the degree to which students have reached their learning objectives. The time of the result is usually right after an oral defense. The expectation is clearly formed during the project and evolves up until the report is submitted.

The projects discussed below range from projects carried out in project-based courses to the final projects of an M.Sc.Eng programme. They all involved handing in a report and an oral defense of the work, and they were all conducted at the Technical University of Denmark or the University of Toronto. Fortunately, both institutions use grading schemes which are compatible with the A to F scale where A is the top grade, E is lowest passing grade and F is fail.

Initially, there is a brief description of the student and the project. The students are referred to by a code of the form Sx where x is a number, and the precise topics have been veiled to make the students anonymous also in practice. After the initial description, a fact box contains the following data for all students: 1) who had the *original idea* (advisor or student), 2) What was the advisor's *expectation*, 3) what was the *result*, i.e. actual grade passed, 4) to what extent did the student systematically *attend supervision*, and 5) our brief *assessment* of the main issue.

Student S1 had the task to design and implement a method within a game engine. The task was theoretically challenging for the student, and it led to advisory sessions where the supervisor acted as a consultant for the student, helping him choose between strategies and in some cases suggesting concrete solutions. While this was useful for the student and pleasant for the advisor, it left too little time to discuss the structure of the final report and how to best document the usefulness of the implemented feature. The end result was a program that seemed to work fairly well but was poorly tested. Moreover, the report contained too little theoretical background. As such, it was fairly good work, but due to lack of experiments and comparisons, it was hard to assess just how good.

Original idea: Student
Expectation: B
Result: C
Supervision attendance: attended supervision groups, many additional one-on-one sessions.
Problem assessment: Insufficient knowledge of previous work demonstrated in report. Insufficient testing of own work.

Student S2 was given the task of designing an interface for digital sculpting using technology for providing 3D input. The student was excited at the prospect of using cutting-edge input technology and designed an elaborate system, assuming perfect plug-n-play input. The student was advised to test the entire project pipeline with the simplest possible functionality but did not do this. Mid-way, the student got mired into interfacing with the technology and discouraged by the noise and inaccuracy in the input. The final outcome as a result was less than impressive.

Original idea: Advisor
Expectation: B
Result: C
Supervision attendance: S2 met with the supervisor and was helped by other students who had experience working with the input technology.
Problem assessment: Should have identified the potential pitfalls in integrating various components of the system and tested the overall pipeline early. This could have better informed the focus of the project, and the implementation of the final system.

Student S3 was given a challenging project where the goal was to design and implement a program to synthesize a class of computer graphics objects. The task was based on a preexisting program which was to be extended. The student did an admirable job and solved the problems quite well. The trouble was that the success was not as clearly presented as the examiners would have liked. There were fairly few examples, and the significance of the results was not quite clear. An important issue is that the external examiner in particular found the results poorly documented. Clearly, the advisor was in a much better position to appreciate the results.

Original idea: Advisor
Expectation: A
Result: B
Supervision attendance: S3 attended supervision groups.
Problem assessment: Insufficient clarity in report regarding the significance of own work. More results (examples) had also been helpful.

Student S4 was a group of two students tasked with creating an interface for stylizing video input. The original idea was proposed by the students with a flurry of ideas that sounded promising. The folly with this project was that it was defined in terms of creative tools without a clear measure of success in terms of how the tools would be used or benchmark examples of stylized video that one might create using this approach.

Original idea: Student
Expectation: A
Result: B

Supervision attendance: S4 met with the supervisor regularly and were quite motivated throughout the project.
Problem assessment: Despite their motivation their project suffered from a bottom-up design without a clear unifying rationale for the bottom-up pieces. As a result, they only had small toy examples that illustrated different tools but not how they might all be useful together. There was also no clear division of labour between the students up-front that lead to friction between them.

Student S5 was asked to explore a model for surface illumination. The advantage of the model was its simplicity. Potentially, it would be possible to obtain the appearance of a far more complicated model at very little computational cost. The student - while initially agreeing to the project - was later unhappy that it did not include elements of well known, but far more complicated models. Ultimately, S5 dropped the project after it became clear that S5 was unwilling to proceed along the lines suggested by the project advisors.

Original idea: Advisor
Expectation: B+
Result: Dropped project
Supervision attendance: stopped attending
Problem assessment: advisors and student did not agree on goals and methods.

Student S6 was asked to find salient feature in 3D animation. A number of algorithms were discussed in sufficient detail. After a few false starts, where aspects of the problem and solution were misunderstood and a few more unsuccessful attempts, the student switched to the related problem of visualizing motion trajectories. Here again, the task was perceived as a bit vague and progress was minimal.

Original idea: Supervisor
Expectation: B
Result: C
Supervision attendance: S6 met with the supervisor one-on-one but had a tendency to disappear when there was little progress to report.
Problem assessment:Throughout this project there was a tendency to give-up that caused the supervisor to continually shift the project focus, without much success. In retrospect, this was a mistake and the original project once decided should have been left unaltered.

Student S7 wanted to create a system for modeling scenes. The student's original idea was very challenging and not quite clear. It took considerable advisory effort to shave the ideas down to something that was commensurate with the student's skills. In the end, S7 did produce a system, but one that contained little that was novel and fell far short of the original vision.

Original idea: Student
Expectation: C
Result: E
Supervision attendance: did not attend.
Problem assessment: student lacked fundamental skills. Did not seek advice often.

Student S8 was given a task with a clear connection to the advisor's research. Specifically, the student was asked to extend and improve a method previously published. In retrospect, the strategy chosen was not the best, and this the student cannot be blamed for. Unfortunately, the student also did not explore certain areas deemed essential for the success of the project. Thus, the results were less than impressive, and although they might not otherwise have been entirely successful, it was not fully uncovered by S8 where the problem might lie.

Original idea: Advisor
Expectation: A
Result: B
Supervision attendance: attended regularly.
Problem assessment: advisor and student did not agree fully on method.

4 PROJECT SCENARIOS

Our objective is to provide a tool for recognizing a student who is likely to fall short of expectations, early, during project work rather than during assessment, so that remedial action can be taken. To achieve that goal, we need to reduce the issues encountered in the projects just described to a few recognizable scenarios. In the following, each scenario will be given a name that reflects the type of student involved. This could be seen as an indication that we consider the advisor a constant and *blame the student* (Biggs, 1999). Clearly, the problem is with the process and either the student or the advisor or both may be to blame. Yet, the student is the one who is graded regardless of whether the advisor did a good job. For this reason, we have chosen to keep our focus on the student. We will happily acknowledge that other, better advisors might have kept students such as ours from traps that we allowed them to walk into. The point of this paper is to train ourselves and inform others about how to avoid these traps.

With this in place and having analyzed the projects above, we find that the following three scenarios describe our problematic projects well.

The Dependent Student (S1, S6)
Some students are not terribly independent or appear so, because the advisor is highly interested in the project. This easily leads to advisors spending more time with these students than they might otherwise, but that may not be a good call. In the case of student S1, the result was that discussions with the advisor to some extent reduced the perceived need for independent research and led to a report considered "thin". In the case of S6, the project focus was shifted when progress was lacking, causing erroneous student perception that roadblocks could be addressed simply by shifting or reducing the scope of the project.
The trap: seeking and following the advisor's counsel is generally a good idea. Thus, the lack of independence can, occasionally, be discovered rather late.

The Brilliant Underachiever (S3, S4)
Perhaps the most saddening scenario is when the student is highly talented, yet fails to deliver something that lives up to expectations. In the case of S3, we needed more results to demonstrate the method and a more clear exposition of the advantages of the work. In the case of S4, the students failed to show how the individual parts could work together, and this was an important aspect.
The trap: progress might seem satisfactory - even impressive. It is only towards the end, when the pieces come together that the advisor realizes shortcomings in how the work is tested and presented.

The Teflon Student (S2, S5, S7, S8)
Student S2, S5, S7, and S8 refused to do something that the advisor deemed important. What seems to happen in these cases is that the student has a strong notion about what is

important in the project. The advisor then asks the student to do something that does not fit well into the student's mental framework for the project. It could be that the advisor suggests something considered to be a shortcut (S5), a tedious detour (S2, S8) or just not what they had in mind (S7). It could also be that the advisor considers himself (or herself) to have been more clear about what is expected from the student than is perceived by the student.
The trap: in our experience, people rarely (flat out) refuse to do things. Instead, they simply do not get around to doing them. Again, this can lead to problems being discovered late.

5 ADVICE FOR THE PROJECT ADVISORY PROCESS

In a sense, we have arrived at the embarrassingly simple conclusion, that the advisor and student must continually match expectations. That is known. What is surprising is how difficult it can be in practice. One could argue that this is simply because "all unsuccessful projects are somewhat different". For precisely this reason, it is folly to think that our three categories capture every single instance of a student who fails to meet expectations. Yet, the categories are very broad and it does seem that many cases of learning deficit can be attributed to one of these three scenarios. We hope and believe that putting a name to the issue will help overcome it.

Thus, our advice is that the advisor should monitor his or her students throughout the project period and try to pigeonhole them into one of the three scenarios. Hopefully, they do not fit, but a student recognized as a

- *dependent student* should be made aware that too much steering of the project will negatively influence the result since the lack of independence is likely to shine through.
- *brilliant underachiever* should be made aware that it is not the raw technical results so much as how these results are explored and presented holistically that is the basis of assessment.
- *teflon student* should be made aware that refusal to take advice is at the student's own peril.

While some students might need only a subtle hint to understand that they should change something, it is more likely that "making aware" requires that the advisor frequently repeats that they are in danger of falling into one of these categories.

Furthermore, the best way of avoiding these traps might be to discuss the three scenarios with the project students and ask them to consider *for themselves* whether they might be in danger of falling into one of them. Of course, a student might find it offensive to even consider whether he or she merits these labels above. It is important to remind students that if they do in fact fall into one of these categories, it is quite possibly due to characteristics of the advisor as much as themselves. We plan to converse about these issues with our own future project students, and we hope that this will lead us to collect very few examples of "learning deficit" in the future.

6 FUTURE WORK

It would be a very interesting future endeavor to extend this analysis to more student/project combinations where a learning deficit was observed. This might be done, for instance, via an online survey where advisors are asked to identify projects with unmet expectations. For each project they would then be asked to assign it to one of the scenarios or, failing that, to explain what went wrong as we did above. Thus, we would a) gain statistics about the frequency of the scenarios and b) possibly formulate new scenarios — if a picture were to emerge where many projects simply did not fit in any category.

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BIOGRAPHICAL INFORMATION

J. Andreas Bærentzen, Ph. D. is an associate professor at the Department of Applied Mathematics and Computer Science at the Technical University of Denmark. Currently, he is on sabbatical visiting the Dynamic Graphics Project at the Computer Science Dept. of the University of Toronto. His research focuses on the representation of digital shape and more generally on computer graphics. His teaching is mostly on geometry processing and real-time graphics. Andreas Bærentzen has been director of studies for the Digitial Media Engineering M.Sc.Eng. programme at the Technical University of Denmark. While on sabbatical, he is on leave from a position as chairman of the study board at DTU Compute. He has supervised two PhD projects, 22 MSc projects and 16 BSc/BEng projects.

Karan Singh is a Professor of Computer Science at the University of Toronto. He holds a BTech. (1991) from IIT Madras and MS (1992), PhD (1995) from the Ohio State University. His research interests lie in artist driven interactive graphics, spanning geometric and anatomic modeling, character animation and sketch based interfaces. He has over 100 peer reviewed publications, has supervised 5 PhD and over 20 MS theses. He was a technical lead on the animation software Maya (Technical Oscar 2003) and the R&D Director for the 2005 Oscar winning animated short *Ryan.*

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