Assessment Design for Studio-based Learning

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ABSTRACT
Studio-based learning is not new to computing education, however as the ecosystem of available Open Educational Resources (OERs) expands, the capacity and desire for student self-directed learning is growing. However increasing student autonomy in how and when learning takes place creates challenges around assessment. This paper introduces the design of assessment tasks to support studio-based learning at undergraduate level. It describes an example of using learning contracts and portfolio-based assessment for evaluating individual and team performance. The paper presents some initial observations of the approach taken, and its transferability to other areas of the curriculum.

CCS CONCEPTS
• Social and professional topics → Student assessment; Computer engineering education;

KEYWORDS
Student assessment; Studio-based learning; Portfolios

ACM Reference Format:

1 INTRODUCTION
Studio-based learning is not new in computing education, although many examples focus on either a particular subject that was transformed by motivated lecturers [3], or in some cases a particular subject area like Human-Computer Interaction [6] or software engineering practice [8, 10]. However there have been programs that have embedded studio-based learning at every stage within a computing degree [5, 7].

In this paper, we focus on a more recent effort to embed studio-based learning throughout a degree program in data engineering. Data engineering in this context draws knowledge and practices from software, computer systems engineering and data analytics. The focus is on data — including data gathering; processing; analysis and decision making; storage and computation; presentation and action.

Starting in their first year, students complete a ‘Fundamentals Studio’ where they engage in open-ended inquiry and learning to develop basic capabilities in data engineering. They then move into an ‘Applications Studio’ where they focus on one particular technical area within data engineering and take a deep dive into developing technical expertise and capability. Finally they move into a ‘Professional Studio’, where the focus is on developing professional capabilities alongside more advanced technical ability.

Each studio spans two semesters — students will complete Fundamentals Studio A in one semester and Fundamentals Studio B in the following semester. Although they are distinct subject enrolments, students are encouraged to see studio B as a continuation of studio A.

The studios run alongside more traditional subjects — in a typical semester, a full-time student will be enrolled in 3 other subjects as well as their studio. However the studio is not seen as merely applying knowledge previously or concurrently gained in other subjects to implement a project. Students also engage in individual learning throughout the studio.

The goal of this paper is to focus on one aspect of our experiences in developing this studio approach: assessment. After briefly describing the purpose of the studios, we present the assessment design used for the first and second cohorts to enter the program. We hope that sharing this approach to a more individualised and open-ended assessment design may inspire others looking to transform subjects or degree programs towards a studio-based learning environment, or adopting specific assessment practices that encourage student-centred learning in non-studio contexts.
2 PURPOSE AND STRUCTURE OF THE STUDIOS

The purpose of the studio is to provide an environment in which students can articulate the knowledge and wisdom they have gained in other aspects of their program into what they are capable of doing. The relationship between wisdom, knowledge/skill, and capability is central to our notion of the studio. We define knowledge as the accumulation of facts and information that the student has learned or experienced. Knowledge is acquired through study, research, investigation, observation, or experience. We think of skill as being in the same category as knowledge. It is what student acquires as a result of practical experience, and is just another resource, like knowledge, that students need to become capable. Finally we think of wisdom as the ability to discern and judge which aspects of that knowledge and those skills are true, right, lasting, and applicable [1, 2, 11].

2.1 Defining capability

The notion of capability is central to our view of studios. We align with Stephenson’s definition of capability [12]:

Capable people have confidence in their ability to
• take effective and appropriate action,
• explain what they are about,
• live and work effectively with others and
• continue to learn from their experiences as individuals and in association with others, in a diverse and changing society.

This extends beyond the definition of competency introduced in the IT2017 report [9], where competency is defined as:

Knowledge + Skills + Dispositions

In particular, competency focuses on performative ability at a point in time, usually in demonstrating competence working on familiar problems in a familiar context (such as problems and contexts introduced earlier in the semester). Capability is a broader concept. It extends it beyond the individual, the one point in time and familiar context to consider how an individual can work with others, on unfamiliar problems, and manage their own learning needs as independent learners [13].

We do not claim to have solved the challenge of assessing capabilities rather than competencies, however from a perspective of framing the role of studio-based learning, we believe it is important to set students the goal of achieving capability rather than just measuring their performance against a set of competencies.

2.2 Individual and team learning activities

The learning activities in the studio have both individual and team components. Having joined a team and chosen a product, the individual makes an assessment of what the product needs relative to their own and their team’s ability to achieve that product. Students then create an Individual Learning Contract in which they agree on what and how they will acquire the knowledge and skills they need.

On the other hand, the team gets together to define the scope of their product, and create a means of achieving that product. We think of the means as a project and the artifact as a product.

Examples of team products worked on during the Fundamentals Studio (first stage) included:

• analysing and visualising public social media data (Twitter and Spotify) to show mood or sentiment;
• determining whether a hotdesk space is vacant or occupied, by applying object detection algorithms in OpenCV to images captured by a microcontroller and camera;
• implementing an indoor localisation algorithm using a 2D ruler approach to allow a small robot to identify its position;
• implementing a smartphone-controlled door lock over HTTP.

Team projects for the Applications Studio (second stage) are yet to be determined, however the intention of these is that the capabilities developed will relate to a student’s chosen submajor (specialisation). So for example, students who have chosen a cybersecurity submajor should be using the studio to develop deeper technical capabilities in cybersecurity. This does not mean that they have to work only with other cybersecurity students—they may for example be the cybersecurity expert on a team of students developing any data-intensive internet-connected product.

In the Professional Studios (third stage), students are expected to place a higher emphasis on developing personal and professional capabilities relating to their career objectives, alongside their technical development. While this could be about developing professional capabilities for an industry career, it could also be developing entrepreneurial capabilities to create their own startup, or research capabilities if they have ambitions of completing further study. It may be that these later students are working in mixed teams with earlier stage students, where they take on the role of mentor, project manager, product owner and/or technical expert, enabling them to develop their own leadership capacity.

3 ASSESSMENT DESIGN

In designing an assessment strategy for studio-based learning, a number of requirements were considered:

(1) To encourage students to focus on developing wisdom and capability, rather than just the accumulation of marks or a collection of isolated competencies;
(2) To find a balance between individual and team-based learning;
(3) To allow students to develop individual capabilities that are meaningful to them, while still aligning with the overall graduate profile;
(4) To allow students to arrive with different starting points, and to map out learning goals that are at an appropriate level for their experience, while also challenging them to push the boundaries of their abilities;
(5) To encourage students to be mindful of their own professional and personal development.

In the first year of running the Fundamentals Studio, there were only two main assessment tasks: a portfolio assessing individual work, and a team wiki, assessing the team development of the product. In the second year, this was extended to include a Personal Design Journal, for students to document their individual design ideas and contributions to the team product development.
3.1 Grades, not marks
To encourage students to focus on developing capability, it was decided that the subject overall should assign them a grade only, with no mark component. That is, students are graded as Fail, Pass, Credit, Distinction or High Distinction (which contributes towards their Grade Point Average), however they do not receive a numeric mark from 0-100. Rubrics help students and markers to understand what is required for each grade level for each assessment component. The decision not to adopt a Pass/Fail grading scheme was to encourage students to strive for excellence in their work, but being able to define excellence in more qualitative terms rather than the summation of marks.

3.2 Individual portfolio
The individual portfolio is governed by an individual learning contract (ILC). An example of the structure of the ILC is shown in Appendix A. The ILC is assessed early in the semester, to ensure that students are setting themselves learning goals that are sufficiently challenging, relative to their current stage of development. Within the ILC, students are asked to first reflect on the needs of their product, and then assess their current capabilities, and their capacity to contribute towards their product. Using that as a basis, students are then asked to identify areas where they feel they don’t yet have the capability needed for the product development, and these form the basis of their individual learning goals. Even though the product is team-based, each student is asked to think about their individual contribution to the team product, so typically each student’s ILC is different, even though they may be working on the same team.

Students are encouraged to make the goals in their ILC as specific as possible, and to describe how they will demonstrate their learning by the end of semester. For example, it is not sufficient for a student to write “Learn Python” as a learning goal — they must describe how they intend to learn Python (e.g. providing a specific URL of an online course they intend to follow), to what level they intend to learn it, and how they will demonstrate by the end of semester that they have completed the learning and are able to apply it.

This aligns with the approach presented in [4], where students must outline not only activities, but the standard of work, strategies for completing it, resources required, and importantly, evidence of accomplishment and how the evidence is to be evaluated.

The ILC is revisited at the end of semester together with the portfolio, to assess to what extent the portfolio contents address the learning goals originally agreed upon.

The key to assessment of the portfolio is for it to contain appropriate evidence to demonstrate how the learning goals were achieved. The concept of demonstrating learning through providing their own evidence is foreign to most students, who are used to the lecturer setting assessment tasks and deliverables. Therefore, some time is spent in the studio discussing with students the forms that their evidence may take, and encouraging them to collect evidence throughout the semester, rather than waiting until the end.

Students also have the opportunity to self-assess their portfolio before or during the final assessment meeting. This final assessment takes place face-to-face with an academic staff member, giving the student the opportunity to explain and defend their portfolio during the assessment, and providing an opportunity for discussion of the learning journey, rather than merely assessing the artifacts submitted.

The longer-term goal of using portfolio-based assessment is for students to curate their own public portfolio by selecting items from their studio portfolio(s), and to use their public portfolio to promote their capabilities when seeking internships and graduate employment.

3.3 Team wiki
The team wiki provides documentation of the development of the product over time. It is also formally assessed twice during the semester — once near the beginning, when students have worked with their product owners to identify the needs and scope of the product/prototype, and once at the end, when it forms both technical documentation about the product as well as documentation about the process that was followed.

In addition to the wiki, teams also demonstrate their product at the end of semester.

The wiki format was chosen for several reasons. Wikis:

1. are a widely accepted method of online documentation of software projects, and thus reflect an industry practice;
2. encourage students to think non-linearly about the way they present information (compared with writing a report);
3. allow students to have one platform that can serve multiple purposes or audiences, e.g. the wiki can have different sections for user documentation, technical developer documentation, and documentation of the process undertaken;
4. encourage the use of multimedia, for example, embedded videos showing the product working;
5. encourage collaborative editing, where different team members can take responsibility for different pages or sections of the wiki.

3.4 Personal design journal
The personal design journal was a later addition to the assessment pattern. The journal itself is an individual task, where students document their work and personal ideas towards the team product. It provides a link between the other two assessment tasks, as well as encouraging a focus on design that is appropriate in a studio context. From an assessment perspective, it also helps to clarify individual contributions towards the team product.

Students can use any form of journal they wish, however they are encouraged to use a hardcopy journal that they can handwrite and sketch into. The focus is on capturing ideas as they happen, and on sketching rather than writing. The journal is intended to be immutable — not edited to reflect a ‘perfect’ journey through the process — and an opportunity at the end of the semester to look back at progress over time.

4 INITIAL OBSERVATIONS
This section describes some initial observations on the impacts of the assessment design.
4.1 Goal setting
In the beginning, students find it quite challenging to set their own learning goals, and to choose appropriate goals. In the initial drafts of ILCs, goals are often either too generic, not sufficiently challenging, or sometimes even too ambitious. A lot of time in the early weeks goes into helping students refine their learning goals to be challenging but achievable.

From a staff perspective, allowing students to set their own learning goals also challenges the traditional role of the lecturer as the one who defines students’ learning outcomes. It requires a mindset shift of staff away from feeling that it is entirely our responsibility to dictate or control what students learn toward trusting that students (with guidance) will reach their own conclusions about what they need to learn, and if they have the motivation, will learn it without having to be taught in the traditional sense. This shift in thinking is not easy as it challenges the definition of our role as lecturers or teachers.

4.2 Evolution of goals over time
By the end of semester, students have often changed their goals. Sometimes the needs of the product change, and students realise they need to develop new or different capabilities than they originally thought. Or sometimes when students begin exploring a topic that is new for them, they discover new pathways they didn’t know existed. Students are reassured that this is fine, as long as they communicate the changes, and that what they deliver in the end in their portfolio is still of a similar level of difficulty and demonstrates their growth.

Clear [4] presents a case for using the term learning agreement rather than learning contract, to provide a sense that the outcomes are negotiated rather than binding. However the context of this statement was in a cooperative work integrated learning experience for capstone students. We agree with the principle of providing flexibility through negotiation and recognition of goals changing over time. However, as we are currently working with early stage students, the notion of a ‘contract’ is deliberately intended to instill a sense of obligation and commitment. Students are typically meeting their academic mentor weekly, so there is ample opportunity to discuss challenges encountered and renegotiate a new direction. Students are also invited to treat their learning contract as a living document, and update it during the semester based on conversations with their mentor, however in practice this has not been monitored.

4.3 Student motivation
Students are strongly motivated by the team product development. Comments indicate that they enjoy the freedom to take the product development in almost any direction they like (with agreement of their product owner), and in most cases this inspires students to extend their ideas further than they originally thought possible. The products are chosen to be open-ended, with a variety of directions to take, thus enabling a design mindset. Occasionally teams of students ‘play it safe’ and restrict the scope of their product to what they feel comfortable with, but the product owners and mentors play an important role in encouraging students to push their own boundaries, and not to be afraid to try things that they have no idea how to do, or that might not work the first time (it’s okay to fail, because even that is learning). Consequently by the end of semester, students often exceed their own expectations, and frequently exceed staff expectations as well.

One surprising aspect is how well it has worked to provide such open-ended challenges to students in their first year at university, as compared with the approach taken by Hundhausen et al [7] that takes a more conservative view of studios becoming more open-ended in the third year of a computing degree.

4.4 Use of grades rather than marks
The use of grades only rather than marks has had mixed results. In all of the assessment tasks, students were graded against a rubric, initially supported by the subject’s learning management system (Blackboard). One downside to this approach was that the rubric system assigned numeric weightings to the level of achievement against each criterion, which was visible to students. So even though at the end, students did not receive an overall mark for the subject, there was still a sense that marks were important. It was also the first subject students had completed without marks, so they were in unfamiliar territory.

In the second cohort of students joining the studio program, a different online rubric system called REVIEW [14] was used which suppressed the mark details, so students only saw their overall level of achievement against each criterion. Another benefit of this change was that the rubric grading was on a continuous sliding scale, rather than discrete achievement levels. With the discrete rubric, creating these sorts of individual variations was only possible by manually editing the student’s numeric mark after the rubric grading was complete, which creates extra work and reduces the impact of using a rubric if the mark is later adjusted manually. The impact that this change has had on student perceptions of assessment is yet to be fully explored and could be the subject of further evaluation work.

As an example, the criteria against which students’ individual portfolios were assessed in the second studio cohort are shown below:

- Description of the activities undertaken, and their linkages to the contracted activities
- Identification and description of the knowledge and skills obtained, including the uploaded evidence
- Description of the difficulties faced and solutions employed
- Assessment of the individual contribution to the team product
- Presentation and quality of the portfolio

These criteria were then rated on a sliding scale from Fail to High Distinction with indicators for each level of performance, without students seeing a numeric mark. The rubric used is under review (and indeed has so far been modified every semester the studio has run), reflecting not only the difficulty of creating good assessment rubrics, but also the shift from assessing competencies to assessing capability.

4.5 Workload shift
The studio assessment design described here requires more overall academic staff time than more traditional modes of assessment. In the formative stages, significant staff time goes into helping...
students in preparing their individual learning contracts at the start, as well as product owners and mentors helping students to refine the scope and deliverables of their team product.

Summative assessment of both the individual components (learning contract/portfolio) and team components (product requirements and delivery) also take significant time, as this is typically done during a face-to-face interview with the individual student or team.

This is a shift in the workload away from teaching towards mentoring, coaching and providing feedback. In a more traditional subject, considerable time may be spent on preparing lecture materials and tutorial/lab activities. Because there are very few sessions in the studio where an academic is lecturing in the traditional sense, time spent on the subject is diverted instead into assessment and feedback. A challenge yet to be addressed is scaling this approach to hundreds of students (current classes have been up to a maximum of about 40 students).

4.6 Broader applicability to computing curricula

While not every computing degree may need or want to adopt studio-based learning, there are some elements of the approach taken that we believe are transferable to other programs.

It is common for computing degrees to have project-based subjects, however the focus is typically weighted heavily towards the project outcomes, and less on individual capability development, and these subjects are often towards the end of the degree. One suggestion to provide space in the curriculum for students to work on developing individual capabilities of their own choosing, beyond merely enrolling in elective subjects. It is better (but not essential) if this can be aligned with working on a product or project, as it increases student motivation and better reflects the way learning occurs in the workplace.

This may just be a single assignment within a larger subject. It would require students to create a learning contract and map out their own structured path of learning, and how they will demonstrate achievement. Ideally this should be embedded in the curriculum starting from first year, giving students a sense that what is often seen as informal or out-of-class learning of topics they are passionate about is no less important or valuable than structured learning as part of their degree, as well as encouraging students to be independent learners from an early stage.

The focus on capability as opposed to knowledge and skills (competencies) is also an important shift in helping students to prepare for their future careers. Encouraging students either formally or informally to develop a portfolio that demonstrates their individual capabilities is another aspect of the studio-based experience that can be adopted and provide a different way for students to think about their education.

5 CONCLUSION

This paper reports on our experiences with the assessment design used to enable studio-based learning in a degree focused on developing capabilities in working with data. The studio component of the program is designed around developing students’ wisdom and capability, drawing on the knowledge and skills they gain from other subjects and through self-learning.

In isolation, many of the assessment approaches described are not new or novel. Others have used learning contracts, portfolio-based assessment and team projects as part of assessment design. What we believe is novel about the approach described here is:

- The balance between individual and team assessment within the studio. Project-based subjects typically place a strong emphasis on the final project deliverable and less on the individual development of capability along the way. The studio assessment makes these closer to equal in weighting.
- The emphasis on students working with mentors to identify areas where they lack capability, and to devise their own learning plans, using a constructivist approach.
- The early stage with which open-ended problem solving is introduced. It is more common in computing programs for students to work with very constrained problems early in their degree, and leave open-ended problem solving until the end when they have built up a base of knowledge and skills. The studio approach uses the open-ended problems as a way to motivate the acquisition of knowledge, skills and ultimately capability, rather than seeing the work as an application of knowledge previously acquired.

We are still in the relatively early stages of our exploration of studio-based learning, and do not yet have graduates to evaluate the impact of introducing this across an entire degree program. However, our early experiences are positive, and believe that there are elements of assessment practice that are transferable into other computing curricula.

A INDIVIDUAL LEARNING CONTRACT

This appendix summarises the key information contained in the Individual Learning Contract (ILC). The ILC is co-designed at the start of the semester and is the document against which the individual portfolio is evaluated at the end of semester. This section is based on information provided to students, and thus written for a student audience.

Needs of the Product/Prototype

Here the student makes an assessment of the knowledge and skills needed for development of the product/prototype. The student also has a conversation with the other team members to make an assessment of the knowledge and skills currently available within the team. This section will look similar for students in the same team.

Brief description of my product. Provide an overview of the scope of the product to be developed.

Brief description of my team. Document each member of the team, and the knowledge and skills (or capabilities) that they currently possess that are likely to be relevant to the development of the product.

Description of the technical and other requirements of my product. Briefly list some of the key functional and non-functional requirements of the product. This is only an initial list, as the full scope of
the product emerges through ongoing team discussions with the product owner.

Assessment of the student’s capabilities

This section focuses on the individual student, including their current capabilities and areas for development.

Brief introduction to myself. A description of yourself at your current stage of development. This could be what you write in your CV, a cover letter, or a LinkedIn profile.

My stage in the degree program. Provide some context of how this subject fits into your overall degree. For example, describe what year level you are in, what majors/submajors you have chosen, and what other subjects you are studying concurrently.

What studio I am doing. Which studio subject are you enrolled in? What did you do in your previous studio? Is this further development of a product you worked on in a previous studio?

Self-evaluation of my ability to contribute to the product requirements. Considering the requirements of the product and your own capabilities and those of your team members, draw on areas of both strength and weakness to identify:

- how you can use your current strengths in working on this product;
- areas where you have some capabilities useful for creating the product, but would like to develop further depth or expertise;
- areas where no-one in the team currently has a specific capability required for the product, and you would like to develop.

Note that this self-evaluation should include non-technical capabilities as well as technical. For example, capabilities you might like to develop could include oral presentation skills, report writing, team coordination, project management, etc. In every studio, you should consider developing both your technical and non-technical capabilities, and consider whether you are extending your breadth or depth in each case.

Proposed learning activities

The student consults with academic mentors, industry partners, product owners and Google to find possible learning activities. Good sources are places like Lynda.com and Codecademy. MOOC providers also may be used.

Proposed learning activities. It is important to be specific here.

1. What are the specifics of the activities you will do?
2. Who is providing them?
3. How are they assessed?
4. How much time per semester, per week, per day?
5. Is there a certificate provided at the end, or other proof of completion? If not, what alternate evidence will you provide to demonstrate your capability?

It is important that you accumulate evidence that you have done this activity. The evidence should demonstrate not merely completion, but also your level of achievement. Examples of evidence might include:

- A completion certificate
- Screenshots of websites showing sections/modules completed
- Examples of projects completed using the knowledge/skills gained
- Short videos or screencasts of you completing tasks
- A logbook documenting your learning that is regularly shared with the academic mentors

Other proposed learning activities

If there are other activities that the student would like to add to the learning contract, they should added here. These will often be unrelated to the team product being developed, but of either professional or personal interest to the student (e.g. learning French or playing a musical instrument).

Other proposed learning activities. As in the previous section, you must provide specific details of the activity to be undertaken, and a description of the evidence that you expect to be able to provide at the end of semester to demonstrate your learning.

REFERENCES