Studios in Software Engineering Education: Towards an Evaluable Model

Christopher N. Bull, Jon Whittle, Leon Cruickshank
HighWire DTC, School of Computing and Communications, ImaginationLancaster
Lancaster University
Lancaster, UK
{ c.bull, j.n.whittle, l.cruickshank } @lancaster.ac.uk

Abstract—Studio-based teaching is a method commonly used in arts and design that emphasizes a physical "home" for students, problem-based and peer-based learning, and mentoring by academic staff rather than formal lectures. There have been some attempts to transfer studio-based teaching to software engineering education. In many ways, this is natural as software engineering has significant practical elements. However, attempts at software studios have usually ignored experiences and theory from arts and design studio teaching. There is therefore a lack of understanding of what "studio" really means, how well the concepts transfer to software engineering, and how effective studios are in practice. Without a clear definition of "studio", software studios cannot be properly evaluated for their impact on student learning nor can best and worst practices be shared between those who run studios. In this paper, we address this problem head-on by conducting a qualitative analysis of what "studio" really means in both arts and design. We carried out 15 interviews with a range of people with studio experiences and present an analysis and model for evaluation here. Our results suggest that there are many intertwined aspects that define studio education, but it is primarily the people and the culture that make a studio. Digital technology on the other hand can have an adverse effect on studios, unless properly recognised.

Index Terms—Software Studio, Studio, Atelier, Software Engineering Education, Creativity, Collaboration, Collocation, Design.

I. INTRODUCTION

Software engineering is an inherently creative process [1][2] and it is very beneficial to learn with other students [3]. To support this, we should ask: are the environments that we learn in suited to promoting a collaborative culture that is sensitive to creative processes?

There are many approaches to learning that can be utilised in software engineering, ranging from traditional structured approaches (such as lectures and homework) to more agile ones (such as interactive seminars and project-based learning). Both general approaches have various benefits and drawbacks (and stereotypes) of the environments that the students work within, individual and group work, and work ethic. A traditional lecture is an efficient method for broadcasting information to many students. On the other hand, project-based courses engage the students, therefore increasing motivation and can better support a learning-by-doing approach, especially by allowing students to “apply system-level thinking” [4].

Brooks recalled memories where “two programmers in a remodelled garage have built an important program that surpasses the best efforts of large teams” [2] and then posed the question “why then have not all industrial programming teams been replaced by dedicated garage duos?” Here, two teams achieve different results, not too dissimilar to what could be expected of the differing learning approaches. What is it that this duo has, that a large company therefore does not? Students do not generally, if at all, work on large complex systems during their education, so institutions could get away with using traditional teaching methods (if students did not find them boring). An approach that looks to develop complex interrelationships could possibly better prepare students for real-world systems development - especially reflecting on non-technical skills such as communication and the ability to work in a team [4].

Looking towards the creative disciplines (design, art etc.) that face similar challenges with learning and teams, there are aspects of their working environments which, from the outset, appear to promote a range of advantages, some of which include collaboration and creativity. These environments are called studios - open working environments where students do visually-centred work; a more in-depth look at studios informs us that they are used for “reflective practice” [5] (observing and refining practice in a continuous cycle), coaching and peer-learning. Although previous research has linked the type of activities and problems faced by architecture students (building, not software) with those of software engineering students [6], a concise model of studios will lead to a better understanding of them.

This paper explores examples of studio definitions and software studios, highlighting important trends and aims to offer a better understanding of the term "studio" and its use in education. To do this we have conducted 15 interviews, and have analysed them using qualitative methods. The interviews involved a variety of people with a range of experiences in studios, reflecting on their individual perspectives of studio education and their multi-faceted understanding of the environments. This paper presents the results of the analysis of the interviews, and through that, offers an initial model of
dataset. The model provides a set of criteria upon which to evaluate the authenticity and extent of a studio. Our results suggest that it is the people and the culture that have a significant effect on a studio, although there are many variables aspects that define studio education. The most contentious aspect of the studio is the use of digital technology. It can adversely affect the use of a studio by undermining the other elements in the model, however when properly recognised digital technology can be very beneficial in a studio.

The intention of this paper is to bring the topic of studio education to the forefront of the software engineering community, encouraging future work and discussion in this area.

II. BACKGROUND

Studios have existed for centuries, with roots found in schools such as École Des Beaux Arts (mid-17th century) and the Bauhaus (early 20th century). Nowadays studios in schools of art, architecture and design are still common place; however, an agreed upon definition of studio education appears to be missing.

A. Studios Lack a Succinct Definition

By no means is it suggested that no understanding of studios exist, far from it; however, descriptions and definitions of studios appear vague, and it is clear that an understanding of their complex nature resides in tacit knowledge - literature cited in this section refers to studio education in arts and design. A studio could be the physical space, the teaching style or even the attitudes of the students. There are many nuances that are not covered in a succinct definition of a studio, especially as each varies depending on its context, as “evidenced in the tremendous diversity of content and methods in studio teaching in different schools and even within one department” [7]. Not much is understood still about studio learning and what goes on within the studios [8], as they are often “characterized by multiple and sometimes contradictory goals, implicit theories and inherent conditions of ‘inexpressibility, vagueness, and ambiguity’” [7].

Despite the fact that there appears to be no agreed definition, there are many thinkers that have provided important observations and definitions of elements within studio education. The most widely cited thinker, Schön, distils a core concept of studio education, “reflective practice” [5], a form of reflective “learning by doing, with the help of coaching”. For a long time it was considered that there was a “lack of clarity over the purpose and effectiveness of the design studio” [7], even though at the same time it “has been held up as a highly sophisticated means to teaching creative problem-solving” [7]; dealing with this complexity and vagueness is part of the paradox of learning how to design [5], which means that you learn through doing it, but cannot do it until you have learnt it. Another important facet of studio education is the use of critiques [5], and they are widely considered an “indispensable tool” [9]; critiques come in various forms ranging from formal to informal, and individual or group – used as a mechanism to communicate ideas and evaluate designs.

The purpose of the studio seems well documented, teaching the paradox of design education, but a model does not appear to exist to reflect on when implementing your own studio – it is likely more of a culture passed down through generations of designers based on their implicit experiences, as there are many intangibles that make up a studio. Though it is not succinctly defined, there are many descriptions of what a studio is and what goes on within it – which has led to attempts to utilise studios in other disciplines, trying to replicate the benefits that studios afford Design. However, if you cannot concretely define a studio, perhaps you can model it instead to assess its effective implementation?

B. Software Studios

Despite the lack of a definition, several studios have been implemented in software related courses, although they can vary widely in implementation from each other. The earliest known software studio appeared in 1990 at Carnegie Mellon University (CMU), offering a Master of Software Engineering with a “significant studio experience” [10]; this implementation of a studio has reflective-practice at its core, enforced by the nature of “constant questioning” and by assigning faculty members to students as coaches. This studio experience still appears to be ongoing. Some other prominent software studios that followed included a software design studio course at Massachusetts Institute of Technology (MIT) [11], and the ‘Bachelor of Information Environments’ at the University of Queensland (UQ) [12]. More have also attempted a studio-based approach in recent years (c.f. [4] [13] [14] [15]).

Even though studio-based education is occurring more often, there are few that have completely overhauled their respective courses to be fully studio-based; often the studio is simply used for one of several modules that run during a term/semester, and sometimes the studio is only used for critique and discussion and not, for example, the labour of the task. Furthermore, students may spend limited time in the studio, in some cases they are being used “roughly one day a week” [16] – this is contradictory to what is observed of design or architecture studios [5]. Software studios are often only seen as environments used for group work. The down side to this is that there would be no individual projects being worked on in the studio – the studio is also intended for individual work, because the student benefits from being in an open environment around other students.

Evaluating software studios to determine if they are in fact a studio appears to be an under-developed area of research. Yet there are evaluations that compare an implementation of a studio to its traditional (non-studio) counterpart, to determine its effectiveness at teaching the course, stating that the “studio-based learning model offered significant benefits to students in terms of both course content mastery and programming achievement” [15].

C. Shifting Sands

Recent research continues to recognise the need to improve our learning environments [17] – regardless of whether new
environments are studio-based or not, the trend is shifting towards more flexible open spaces which promote group work. The evolving spaces that are required blend “instruction, course work and social interactions” [17].

Current students are considered digital natives (known as Generation Y) [18]. These people have developed years of rich interactions with the digital world in their personal lives, making certain aspects ubiquitous with everyday life. Yet these rich interactions are not supported in many work environments [18]. How will computing education environments catch up with Generation Y?

III. MOTIVATION

There is obviously a vision out there for creating a software studio that people are striving for, yet, with the lack of a definition or model to follow, the authenticity of attempted software studios is brought into question. This means when people try to create a studio they often discover things for themselves. This is ok, but to make the studio move to a mainstream role where the benefits can be more widely felt, we need a better understanding of the ingredients that make a studio. This will allow such things to be transformed or managed to suit different scenarios, or indeed the fact that it is a different discipline.

But before we can do that, we first need to develop an understanding of the key factors at play within the studio, because “there is a danger that an improperly administered studio will degenerate into yet another project course” [10].

IV. METHOD

To achieve a better understanding of studios, leading to a definition or model to evaluate against, multiple peoples’ perspectives and experiences of studio spaces would be needed. 15 interviews were conducted with a range of designers, architects and artists – the interview participants would help inform a model of what constitutes a studio space.

The outline of the approach to this investigation is based on Grounded Theory (originally proposed by Glaser and Strauss [19]) and is used to create a ‘theory’ from gathered data; this is the reverse of more traditional scientific methods whereby a hypothesis is derived and then data is gathered and analysed to prove or disprove the hypothesis. This tactic is utilised because of the exploratory approach to understanding studios across multiple disciplines, essentially allowing a theory or hypothesis to emerge from the interview participants. The process used is described below.

As this research is about determining how people view studios and work within them, we expect different responses from a variety of people as the interview participants come from various backgrounds and even different topics or disciplines. The complex variety lends itself to a qualitative analysis that is data driven.

A. Interview Participants

A call for interview participants was sent out to Design and Architecture departments in several universities in the UK; no software engineers were interviewed during this investigation as the purpose was to understand the studios in the creative disciplines first. Based on a recommendation, one participant (A) was asked to interview outside of the call for participation. 15 participants were interviewed and the respondents are used anonymously.

In the call for participation it was requested that the participants had experience in at least one of the following areas:

- Were educated in a studio
- Have taught others in a studio
- Used one in practice (e.g. in industry)

All of the respondents had experience teaching and being taught in the studio, and seven had used it in practice. Table I shows the breakdown of the participants and their experience.

The final list of participants consisted of 6 universities, but a total of 8 separate departments; for example, a participant may be from Design at a university, and another participant may be from Architecture at the same university. The participants had a variety of experience and positions; for example, some of the participants were lecturers, studio tutors and course directors. Although participants currently work in a UK university, several of them have experience working and learning in studios abroad including USA, Portugal, Italy and Thailand. Each participant was given the option of anonymity, which most of them chose. This allowed participants to speak freely even though no sensitive issues were on the agenda.

<table>
<thead>
<tr>
<th>Participant</th>
<th>Discipline</th>
<th>Studio Experience</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Art</td>
<td>Educated X Taught X Practice X</td>
</tr>
<tr>
<td>B</td>
<td>Design</td>
<td>X X</td>
</tr>
<tr>
<td>C</td>
<td>Design</td>
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<tr>
<td>D</td>
<td>Design, Art</td>
<td>X X X</td>
</tr>
<tr>
<td>E</td>
<td>Architecture</td>
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<tr>
<td>F</td>
<td>Design</td>
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<td>Design</td>
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structured, the participants could lead the conversations and discuss the aspects they thought were of significance.

As the interviews were semi-structured, there was no concrete list of questions, but there was a list of topics and ‘starter questions’. Some of these questions were intended to get the participant to describe an environment, and others were developed based on background reading (to compare perspectives of the literature and the interview participants); the rest of the questions were based on bouncing off of the participants responses. The starter topics and questions were:

- Outline your experience with studios
- Describe your studios
- Describe a non-studio
- Think of a specific project – how was it helped or hindered by the use of a studio?
- What is the ideal vs. reality of a studio?
- Why are studios good?
- Why are studios bad?
- What is the most important aspect of a studio?

As the interview process went on, some additional starter questions were included as they resonated with the interview participants. The interviews were conducted on a variety of mediums including face-to-face and phone, but largely using video-calling software. On average, interviews lasted approximately 45 minutes.

C. Analysis

The interviews were audio recorded and later transcribed. Each transcription underwent three passes of analysis to distil the information into a presentable form: the categories in the next section.

The analysis went through a process of coding and categorisation (a method of identifying unique thoughts or ideas in text and then grouping them around common themes), with the first pass of each transcription dedicated to identifying and listing codes - essentially, a code was anything that stood out. A sanity check for each code was to ask whether it could form part of an answer to the broad questions ‘What is a studio?’ or ‘What affects a studio?’

The second pass of the analysis went over each list of codes and grouped the codes into categories. Each code was judged as to whether it belonged in any of the previous categories made for this list, or whether it warranted the creation of a new category. Realistically, each list of codes was passed over several times to ensure that each individual code belonged to the category that it resides in.

The final pass in the analysis merged the codes and categories of the individual interviews into one holistic list to create the first model of studio education. The categories in this model are the list of categories presented in the next section.

V. Analysis

Interviewing participants with a wide and extensive range of experiences within many studio settings led to 11 unique categories to examine. Each category reflects a factor or property which was reported to affect the studio setting in some manner. Each category is briefly presented in Table II.

<table>
<thead>
<tr>
<th>Categories</th>
<th>Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Defining the studio</td>
<td>N/A</td>
</tr>
<tr>
<td>Physical environment</td>
<td>Open environment, Reconfigurable furniture, Students control aesthetic factors (lighting, heating), Shared spaces, Individual spaces, Social spaces, Private spaces</td>
</tr>
<tr>
<td>Facilitation of studio</td>
<td>Studio belongs to the students, Staff do not dictate use of space, 24 hour access, Food and drink allowed, High availability of staff, Small group size (about 10)</td>
</tr>
<tr>
<td>Modes of education</td>
<td>Switch approach based on activity, Mentoring/coaching, Peer-learning, Impromptu teaching</td>
</tr>
<tr>
<td>Awareness</td>
<td>Visual work, Displaying work, Visual history of progress, Easily observe other people’s work, Social interactions</td>
</tr>
<tr>
<td>Critique</td>
<td>Direct feedback, Develop ideas, Multiple formats (formal and informal, individual and group), Peer-coaching</td>
</tr>
<tr>
<td>Culture</td>
<td>Sharing, Social, Treated like second home, Good work ethic, Peer-learning, Serendipity</td>
</tr>
<tr>
<td>Individual’s characteristics</td>
<td>Personalisation of space, Private and quiet spaces</td>
</tr>
<tr>
<td>Inspiration</td>
<td>Proximity to other people, Relevant available media, Library of liked/fun things, Playful space</td>
</tr>
<tr>
<td>Collaboration</td>
<td>Impromptu collaborative spaces, Supporting equipment</td>
</tr>
<tr>
<td>Digital technology</td>
<td>Not essential for studio, Access work outside studio, Reduces social interactions, Reduces visibility of activities</td>
</tr>
</tbody>
</table>

a. Not part of the model. This category is not an aspect of studios, but a group of conversations related to defining a studio, therefore there are no parameters listed.

b. Studios can exist without digital technology, but it has a significant affect when it does not.
The categories in Table II are presented in no particular order, and are discussed in more detail in a contiguous list below. Note that not all categories are essential in the creation and running of a studio; ‘Defining the studio’ and ‘Digital technology’ are anomalous categories, explained in more detail below, that do not contain features of a core studio. Their existence as categories is warranted because they were discussed significantly during the interviews. To address the inherent complexity involved in understanding them, each is presented with information and quotes from the interviews to help contextualise the issues they represent. For example, how important or dominant that category was to the interview participants, if there were any particularly important relationships with other categories, and further, what was considered good for the studio and what was considered detrimental.

**Defining the studio** – This is an anomalous category which groups anything related to the studio’s purpose (a high level definition) and whether the interview participant thought the studio was worthwhile; in essence, it is a representation of their perspectives of the studio, not a set of features. Some of the interview participants highlighted that studios are too complex to be captured by simple definitions or description, and that there was no perfect space. A studio has multiple purposes and is “a mix between the working space and social space”, with most of the participants having discussed the importance of having other people in the studio. Generally, all participants preferred to use studios, with only one person expressing an indifference to their use. Two of the participants observed a trend where people attempt to replicate the studio setting that they had at university into a professional setting, or in their own teaching style. Other key aspects which were discussed were that it prepares you for work environments, and also that the studio is a creative space. One last important factor discussed was that the studio is not necessary – people can work without one, yet a studio was still a preferred environment for almost all of the interview participants.

**Physical environment** – This category contains anything regarding the physical environment, surroundings and equipment; for example, furniture, layout and location etc. All of the interview participants discussed how the physical environment was important for a studio, but also how it was not the most important aspect, with one person remarking “the studio is created by the culture, not by the furniture.” When asked to describe a studio, another participant said “the only sort of basic, generic kind of description I can think of is that its space...I’ve seen it manifest in many different forms in different places.” Here the studio is described almost as if it was a blank canvas, with the only constant variable being a physical ‘space’.

The participants generally had a positive discussion when talking about the physical environment. One of the most important and commonly talked about aspects was the flexibility of the space (moving furniture, for example), essentially saying that students should not have their activities limited by the rigidity of the space, as some setups are better suited to different activities. Another highly talked about aspect was aesthetic factors such as lighting, heating, but more importantly, control over these aspects. Some other aspects that were discussed were the provision of shared and individual space, the necessity for an open environment (leading to better proximity to others) and social spaces.

Although most of the conversations were positive when discussing the physical environment, there were some negative and detrimental aspects that got some attention, such as openness of space. Although openness of space was generally desired amongst the participants, they pointed out potential issues with privacy, security and disruptive noise. One participant claimed that meeting rooms, not just private space, are essential.

**Facilitation of studio** – This category contains everything relating to staff of a studio and the rules put in place to govern the space. Rules may have been set out by a facilitator (e.g. lecturer) or by the institution (e.g. university or department). Most interview participants agree that the studio belongs to the students, and therefore the staff do not (strongly) dictate to the students how they should use the space (beyond the seemingly common allocated desk). When the students feel that they have control over the environment they will likely use it for activities that are not work related – which is fine. This relates to 24 hour access, which several of the participants said was necessary for a comfortable studio. Restricted access to a studio is bad, as it stops the students from using the space as they want to, for example one of the participants said “you can sleep there, and I slept in my studio so many times, in my student year”. Similarly, students are allowed to eat and drink in the studio too. Another aspect that some of the interview participants thought was important was a high level of availability of staff. Someone always needs to be accessible to provide assistance if required. Several participants suggested timetabled slots that the facilitators would be in the studio, walking around giving advice and getting a general feel of where all the projects are. Some of the participants felt strongly about the size of the group within a studio, depending on the size of the course or year groups you may need to split them up into multiple groups or studios.

Lastly, there was a shared idea that a facilitator could destroy a studio experience; devolving it from a studio to an open environment by imposing rules, reducing serendipitous interactions (like walking around and talking) and intruding on other forms of freedom that a studio can provide. Furthermore, one participant discusses the difficulties with setting up a studio: “I don’t think it’s easy to set studios up, these days; not certainly within a university environment”. This is backed up with comments about how resistant universities are to providing space to be permanently used for a small number of people. Several of the participants talked about an ideal group size for students being approximately 10, and larger courses (for example, 100 students) would split their students into groups of about 10.

**Modes of education** – This category is about the specific learning activities that are performed in a studio. There are a range of activities that will be carried out in a studio, but most
of them will be specific to the subject or even discipline of that studio. However, the interview participants did discuss some common activities, stating that you switch between approaches based on the task at hand. An important mode of learning is the mentoring or coaching approach, where staff take on the role of coach for the student. The most talked about activity was peer-learning, with almost every participant talking about it in one form or another. Peer learning surfaced in several forms, ranging from receiving critique from your peers during a group critique, to a form of peer-coaching. The importance that peer learning has can be seen in this participant’s comment: “A lot of learning happens when you are talking to your colleagues, to other students, in information conversations with the lecturers, not necessarily always lectures.”

Another approach discussed with some of the participants is the use of impromptu teaching. This technique benefits from being in a studio, as the lecturers are expected to be in the studio more often than other courses. Impromptu teaching can happen at any time, but an important trigger may be that the lecturer walks around and sees a common discrepancy in the students’ knowledge, or maybe even a student that the lecturer wants to use as an example to demonstrate something. Of course, another mode of working that was discussed was the solo approach.

Awareness – This category is all about the awareness that an individual will have of his or her surroundings, other people and their work, anything visual (especially visual work) and what this affords them in their studio experience. Several interview participants claim that visual work in a studio is very important, “visual communication is one of the most important things”, with this key skill being developed throughout the studio experience. Visual work is very important to the studio’s ecosystem for many reasons: it allows students to see at a glance what others are doing, it allows students to see how much work others have done and what other people are doing; making easy connections between all of the work that is displayed in the studio. When things are placed up on a wall or left lying around the studio, they become a visual representation of the process, past work and progress. A few participants also suggested that open environments allow teachers to easily observe similarities or common issues amongst a group.

As studios are social open environments, there is more communication amongst peers, leading to a greater awareness of other people’s work – simply through talking. Furthermore, shared spaces within the studio, such as large desks, are used for sharing group work, explicitly improving the awareness of your group, but also that of the other studio occupants.

Critique – This category covers anything about the culture and use of critique. Most of the interview participants state that critique is important in the studio, some even claiming it to be central to many studio experiences. This category could be argued as being a subset of the ‘Modes of education’ category, however the topic of critique was discussed often enough by all of the interview participants, several stating that it is integral to the studio experience, to warrant separating this out into its own category.

A critique is a mechanism with several benefits, the most prominent according to the interview participants is direct feedback; improving the students ability to communicate thoughts and ideas; used as a vehicle to teach students how to contribute to the discussion of other peoples’ work; prepare students to present ideas and handle the responses. One participant shared the idea that the frequency with which you perform formal group critiques is proportional to the size of the class.

The location of a critique can be a sensitive issue, as they can be disruptive and difficult to do in open public spaces where not everyone is involved in the critique itself. This is often countered by booking out a dedicated room for formal critiques. However, in timetabled sessions where lecturers are in the studio walking around, the lecturer gives feedback (informal critique) about what’s good and what could be improved. Several of the interview participants state that critiques can have adverse effect on students, upsetting them, as students grow attachments towards their work which then could potentially receive heavy criticism. One solution offered by one of the participants is to offer the advice or criticism privately after the session, and not in front of everyone. In the run up to a critique session, some students can get motivated to produce similar volume or quality of work when compared to other students.

More often, critique is informally given amongst peers, in the form of a discussion. The studio teaches the students to be critical of each other’s work, which becomes part of their culture. The studio is a great platform for sharing ideas because of this culture of informal critique.

Culture – This category contains all cultural aspects, group aspects, group behaviours and other enculturated dynamics. This is the most dominant category to come out of the analysis. Several of the interview participants identified sharing as an important aspect in the studio, contributing to the open environment by sharing equipment, spaces, and more importantly, sharing ideas.

Another aspect that the participants talked about was the social side, as the studio is considered not just as a work environment, but also as a social environment. There could be communal activities organised within the studio and talking is encouraged, as this apparently improves creativity which “often happens in an informal way like in a conversation in a relaxing atmosphere”; this resonates with others who have said “Software engineers rely on social and casual contact for important communication” [4]. Similarly, another aspect that was discussed frequently was that the studio is treated like a second home with students eating, sleeping and potentially having parties!

Moving back to the work side of the culture, some of the participants recognised that you could make a lot of noise in the studio, and it wouldn’t bother the other participants as that is just the way of the studio; however, other participants noted that all students, perhaps like in any environment, would develop a good work ethic and become sensitive to others that
they share the environment with. Another aspect is serendipity, which was discussed as happening often in studios, not necessarily on purpose – the open and visual environment provides plenty of opportunities to stumble upon something that someone else is looking at or working with. Peer–learning is another aspect that was prominent in the interviews, as it was discussed as being a part of the student’s attitudes towards each other; the informality of the environment means that a discussion could lead to a critique of an idea, which in turn can lead to a form of peer learning or coaching. The studio is said to be filled with students that support and motivate each other.

One last discussion point relating to culture was that empty studios are not as useful as a studio with occupants: “studios can be really bad if people aren’t in them because you’re on your own a lot... the one thing about studios is they’ve got to be lively, I think, to be creative”.

Individual’s characteristics – This category contains aspects that relate to an individual’s personality, their attitude in or towards the studio, and their social and personal wellbeing. Through the analysis of the interviews, and observed by the participants themselves, each discipline, topic and even person will value different aspects of the studio. Some people inherently prefer group activities, whilst others prefer solidarity. A studio should try and cater for both, even though it leans towards group or social environments. Sometimes there is a need for privacy or quiet, and some participants suggested the need for dedicated rooms or spaces to cater for this – open environments have the possibility of becoming noisy and disruptive.

One sensitive issue that was discussed was how some students are uncomfortable essentially being on display, especially if they are new to such environments. Privacy can be an issue for some people, and the open environment does not help this matter, but it was discussed how learning to cope with this is more beneficial than providing permanent private space. One participant described feelings of being judged by others as you compare your work to someone else’s on display. At the same time it was said to be a motivating factor as well, potentially making students feel good about their work when others enquire about it.

One last factor for this category is the importance of personalisation of space; for example displaying work where you want, leaving equipment on your desk and collecting inspirational items. This leads to a better sense of ownership of the space, however, messy people can possible overwhelm the space and disrupt others.

Inspiration – This category contains anything about inspiring ideas and what inspiration can be achieved from. Many of the interview participants felt strongly about the need for inspiration and inspirational materials. Inspirational materials are generally context sensitive to the type of work being done, for example a furniture designer would typically have more items related to furniture. The core concept that one participant discussed was that ideas require stimulation, and it is often referred to in the context of visual inspirational items around the studio (previous work, posters etc.); studios embrace this “quite heavily”. A feature of the studio that the participants with a Design background sometimes talked about was a “library of things” or room of inspirational items. One designer gave the example of seeing and buying things and then placing them in this library, building up a collection of items that inspired them. Another participant claimed that a person that has had less time immersed in similar environments, lacking time to build a store of tacit knowledge from these items, is less capable. Also, many participants discussed the usefulness of having a variety of media on-hand in the studio, with a collection of various magazines for example.

Inspirational studios were also said to be playful, with some participants mentioning that playful spaces are good for generating ideas, and that the space would benefit from having “toys”. The toys could be relevant to the work, or something that the individual liked. This comes back to what one participant said about informal spaces being good for creativity.

One last aspect about inspiration was discussed as benefiting from proximity to other studio users. Having other people in the studio allows people to frequently, and easily, share and discuss ideas and their progress.

Collaboration – This category covers all collaborative related activities, not simply group activities taking the form of division of labour. As stated in other categories, the studio’s usefulness relies upon having students occupying the space; because of this, most interview participants expected that collaboration would take place in the studio. One participant said that the studio was a hub for collaboration and that the studio experience is diminished when people are not very collaborative. Another participant even claimed that an environment is not a studio and just an open space when its occupants work as individuals all the time.

An important factor of collaboration in the studio is the serendipitous and impromptu nature that collaboration can take. Firstly, the studio offers opportunities for occupants to collaborate with others that they may not have thought about, due to the open nature of the space. Secondly, the studio needs to offer impromptu collaborative spaces (that don’t need booking or setting up), as one participant discussed how collaboration can take place at any time.

One last smaller point that several participants mentioned was the need for easy access to equipment; the examples they gave were stationery, such as pens, paper, sticky notes etc. Other facilities that they discussed to improve collaborative activities were digital and online services, primarily for when collaborators could not come together, not as a replacement for face-to-face interactions.

Digital technology – This is all about how digital technology can be beneficial or detrimental to a studio - primarily the computer and similar devices. This is an anomalous category, because unlike the other categories, it does not affect the definition of the studio; a studio can exist with or without any form of digital technology, activities can be purely pen and paper for example. However, this topic cropped up a lot in many of the interviews, and the interview participants felt strongly about this topic. Some participants
noted how digital technology allows for easier access and ability to perform work outside of the studio, but at the same time acknowledge that social interactions within a studio are not repeatable with digital media.

Some of the participants thought that computers were indispensable, one remarking that they were a “massive help just in every single way”, but the majority remarked on how detrimental they all are to the studio experience, one stating that “using the computer has taken us away from working in teams”. Computers create a culture of isolation, with all of your work and activities hidden behind a screen; the author refers to this as ‘Monitor Vision’ or ‘Tunnel Vision’. Similar thoughts have been expressed by others outside of this investigation: “We fear that computers may devalue the art and craft of architecture, decrease collaboration, isolate students, and emphasize product over process” [20].

Throughout the interviews it was made very clear that computers are detrimental to studio culture. The points raised by the interview participants were made independent of the specific activities, and as such are just as relevant to other disciplines (including software engineering), as they were not talking about a specific design activity being inhibited, but general interactions, communication and awareness. As software engineers, we obviously won’t be moving away from computers, but this begs the question: what can we do to avoid the negative effects of computer work? A further interesting question is: what innovation will replace the computer monitor, will our attention still be monopolised in a single direction, i.e. at a screen?

VI. MOST IMPORTANT ASPECT OF A STUDIO

Each interview participant was asked what they thought was the most important aspect of a studio; all but one was able to answer the question. According to the participants, the most important aspect of the studio is “The people in the space”, which resonates with the analysis in the ‘Culture’ section. Here is a list of what the fifteen participants considered the most important aspects of a studio:

- **7x** participants said that it was the “people” that were important
- **1x** Peer-learning; this is separate to the seven that said “people” because it is a specific learning activity
- **1x** Facilitation of the space
- **1x** Open and flexible space, that supports creative activities
- **1x** Movement around the space (i.e. not static rows of chairs)
- **1x** Freedom to work as you wish
- **1x** Serendipity of ideas from close proximity to other people
- **1x** The ability of the individual
- **1x** Unable to answer the question (due to complex nature of a studio)

VII. RELATIONSHIPS

All of the categories presented were generated through the analysis of the interviews, and essentially show the core discussions had with the participants. These categories have relationships with other categories, some more than others. This section outlines some of the prominent relationships between these categories, of which the ‘Physical Environment’ category is quite interwoven with other categories. Each notable relationship identifies the related categories and is then followed by a description:

- **Physical Environment – Mode of Education**: Switching freely between different learning approaches is made much easier with a varied and flexible space; for example, instantly switching from a solo activity to an ideation space. Also, the solo mode of working needs to provide adequate provisions for a quiet environment, allowing the students to get on with their work.
- **Physical Environment – Awareness**: The space can potentially reduce awareness of what’s going on in the studio if it has a bad layout, or there are other physical attributes that isolate individuals. Another issue is that there may be limited wall space to display certain types of work.
- **Physical Environment – Individual’s Characteristics**: Serendipitous awareness is helped by the open and visual environment as it provides plenty of opportunities to stumble upon something that someone else is working on by simply looking across the room or even walking back to a desk with a coffee.
- **Physical Environment – Individual’s Characteristics**: The openness of a studio, desired amongst the interview participants, could potentially be at odds with a student’s requirements for privacy and security in their learning environment.
- **Awareness – Inspiration**: Having some awareness of your surroundings, other people and their work can potentially be good for inspiration.
- **Awareness – Collaboration**: Having an awareness of what is going on in the studio could lead to impromptu collaborations.
- **Critique – Culture**: Open cultures that freely share and discuss ideas in a studio will inherently lead to a form of critique.

VIII. DISCUSSION

Taking the categories of conversation derived in the interview analyses, we can now say we have a better understanding of people’s views of what a studio space is in the context of education. Based on the discussions with the interview participants, it is the people and the culture that make a studio, not the environment, although the participants did speak highly of the physical environment category.
Without an agreed definition or understanding of what a “studio” is, software studios cannot be properly evaluated for their impact on student learning. Due to the complex nature of a studio it is inherently difficult to succinctly define what a studio is, as explored in the background section of this paper. The people and the cultures that create a studio cannot be encompassed within one definition. As such, the analysis in this paper aims to provide a broader understanding of studios in place of a single definition.

A. Towards an Evaluable Model

Based on this enhanced understanding of studios an evaluable model can be provided to determine the authenticity and extent of a studio. The model, provided as Table II and associated descriptions, is derived from the categories discussed in the analysis, with the exception of ‘Defining the studio’; although this was a dominant topic of conversation during the interviews, this category does not represent an aspect of a studio - for this reason it is not included as part of the model. The category ‘Digital Technology’, although not always present or necessary in a studio, has been included in the model because the analysis showed that technology can have a significant effect on a studio. It is intended that this factor will provide examples of potential conflicts that technology has with the other categories, such as reducing social interactions. Determining whether a software studio is an authentic studio will clarify if the students that use it have the potential to benefit from the creativity that a studio supports.

The model in its current form requires subjective interpretations of a studio for each of the categories. To easily represent and share the model after an evaluation, it is suggested that a radar chart is used; an example, with arbitrary values, is given in Fig. I. The 10 axes are named as the categories.

B. Transferring the Model to a Software Studio

The studio evaluation model is generic enough that all of the aspects are capable of transferring to software studios. Certain development approaches will work well in some of the model’s aspects, such as extreme programming (XP) as it “encourages social interactions” [21].

There are three categories which could potentially be cause for concern: ‘Physical Environment’, ‘Awareness’ and ‘Digital Technology’. All of these could have their issues overcome, but they are the most likely to cause issues. Awareness could be severely limited due to the heavy reliance on computers. This is a classic example of where “monitor vision” could have adverse effects, with most or all work hidden behind monitors. Another likely issue would be the physical environment as most computer-based rooms can often have the computers locked to the furniture and plugged into the floor, making tables difficult or impossible to move. Another possible concern is the digital technology aspect, as software engineering is inherently computer-based, how much will they affect the other aspects.

There are several avenues of future research regarding this model; first of which would be to assess whether the model is appropriate for evaluating studios. This would then naturally lead on to a series of evaluations of studios using this model. Further research beyond that would then be able to determine if studios in software engineering are indeed effective and that the effectiveness is not simply a by-product not related to the studio. Finally, intriguing questions can be asked about the differences between studios at separate institutions and whether we can easily identify and transfer elements of one studio to another.

IX. Conclusions

It is recognised that software engineering is an inherently creative process [1] [2] and it is very beneficial to learn with other students [3]. To explore the benefits of a software studio for software engineering students it is essential to first determine what is a studio.

This paper provides the tools necessary to determine the authenticity and extent of a studio by contributing three elements. Firstly, an analysis of the interviews is shared, which includes a list of the dominant categories discussed and how they interrelate, to positive or detrimental effect. This provides a broad understanding of studios to counter the lack of an agreed upon definition. Next, a model to evaluate studios against is provided, which is derived from the analysis. Lastly, a discussion is given about how the aspects of the model may transfer across to software engineering and what the key challenges are.

Now that studios can have their authenticity evaluated, software studios can be properly evaluated to determine how effectively the studio aspects have been implemented. If a software studio is evaluated, it could then be determined whether the students have indeed experienced the benefits that a studio is said to provide and support – or whether there are any inherent incompatibilities between studios and software engineering education. One potential avenue of future research, considering these possible incompatibilities, would be to identify missing or diminished attributes using the model, develop and deploy an artefact in the software studio and see if improving that attribute helps.
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