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Integrating small-scale fabrication technologies in design education for enhanced studio-based learning

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Abstract

The evolving landscape of Industrial Design education requires a balance between theoretical instruction and hands-on experience with manufacturing processes and relevant materials. However, many traditional teaching methods do not provide sufficient opportunities for students to engage directly with fabrication and material manipulation, limiting their ability to develop practical skills essential for the industry. The lack of integration between conceptual design and real-world manufacturing techniques creates a gap in industry readiness. To address this challenge, this study explores the integration of small-scale countertop sized fabrication tools and machines within the lecture venues to create an immersive Studio-Based Learning (SBL) environment. By embedding these tools directly into the educational space, students gain hands-on experience with material manipulation, prototyping, and iterative problem-solving. This approach bridges the gap between theoretical design concepts and the realities of production, drawing on principles of Embodied Cognition that emphasise learning through physical interaction. Through engaging with a specific group of students over multiple projects, this study has demonstrated that students who engage with small-scale fabrication tools exhibit improved proficiency in traditional manufacturing methods, greater confidence in hands-on material manipulation using larger more intimidating machines, and an increased ability to apply practical skills to their own design processes. The opportunity to physically prototype and refine their designs fosters a deeper understanding of materials, production techniques, and product feasibility. Embedding traditional manufacturing approaches into Industrial Design lecturing studios not only enhances students' technical competencies but also cultivates an innovation-driven and practice-oriented mindset, where students are not afraid to take action to initiate the process. This approach ensures that graduates are well-equipped to navigate the complexities of modern design and manufacturing industries. By emphasising hands-on learning through small-scale fabrication, this study provides insights into best practices for integrating traditional manufacturing techniques into Studio-Based Learning, ultimately contributing to a more effective and industry-aligned design education model.

Keywords: Industrial design education, studio-based learning, traditional manufacture, fabrication techniques, hands-on learning, embodied cognition

Introduction

The changing demands of Industrial Design education call for an approach that meaningfully blends theoretical knowledge with direct, hands-on engagement in material processes and fabrication techniques. Yet, many conventional teaching methods still fall short in offering students adequate opportunities to work physically with materials, hindering the development of practical skills that are crucial for real-world design practice. Furthermore, the enjoyment that comes from hands on learning activities is a great benefit to the field of Design Education as students are inherently innovative, explorative and playful which may have lead to them pursuing to study within a creative field.

According to Norton (2019, p. 6), teaching can generally be viewed in two ways: as the delivery of information or as the facilitation of learning. In the first approach, the lecturer's focus is on communicating subject knowledge directly to students. In the second, the lecturer takes on a more supportive role, guiding students as they engage actively with content and build their own understanding. Throughout 12 years of teaching experience in Higher Education, I identify different circumstances for each of these two approaches, and in some scenarios see the generational changes shift over time regarding the way students react to different methods of teaching. In the field of Design, there are many practical and theory modules that require different methods of teaching, and different year groups react to teaching differently.

It is important to reflect on teaching practice in order adapt to the evolving student body. Educators must be able and willing to critically examine their own teaching practices as well as understand how the learners within their classrooms best respond to assimilating what is being taught (Mertler 2016, p. 14).

Theoretical framework

In order to execute the most effective learning within studios, one needs to understand the tasks that can be undertaken within those spaces. In the context of Industrial Design, many critical skills related to small-scale fabrication can be introduced within the studio setting, enabling students to engage with manufacturing theory and techniques in a controlled, accessible manner before transitioning to larger, more dangerous machinery. Within the Industrial Design studio, many learning activities are supported by tangible physical interaction with objects and materials, which is effectively explained by the theory of **Embodied Cognition**, a field of research that suggests the mind and body are not separate. Instead, our physical actions, sensory experiences, and engagement with our environment play a crucial role in how we think, understand, and learn (Wilson & Foglia 2020). As outlined by Margaret Wilson (2002), a leading researcher in the field of embodied cognition, this framework highlights how hands-on engagement gets students actively involved in learning related to these physical tasks. This aligns with the concept that *cognition is situated*, and situated cognition takes place in the context of task-relevant inputs and outputs (Wilson 2002, p. 625). Instead of holding complex information in their minds, students can use physical objects and materials as an extension of their thought process as illustrated by a key principle: the ability to *off-load cognitive work onto the environment* (Wilson 2002, p. 629). The real-world objects they fabricate and the experiments they undertake can serve as external representations of their ideas. This process can allow for a more direct, intuitive understanding of manufacturing constraints and material properties. It also demonstrates that *the environment is part of the cognitive system* (Wilson 2002, p. 630). Furthermore, repeated hands-on practice builds a strong body-based memory, meaning that students can mentally simulate past physical actions to solve problems later, even when they are not in the studio, thereby linking to the idea that *off-line cognition is body based* (Wilson 2002, p. 632). This process is crucial for developing skills and confidence, as it allows them to internalise the practical knowledge gained from manipulating the machines and tools.

Through understanding how students learn effectively, and how the learning carries through into future skills application and confidence, we are better able to identify areas of possible problem-solving within current teaching practices.

Action Research is a particularly suitable methodology for attempting to identify areas of possible problem solving and for developing such interventions in the design educational landscape as it allows for my own experiences and actions to guide appropriate solutions. As educational researchers, those who engage in Action Research examine the teaching environment principles and practices and the effects that educators actions have on the learners within classroom (Relay Graduate School of Education Library 2025).

Action Research is directed toward addressing a particular challenge within a studio or teaching context. It supports informed decision-making and the ongoing improvement of practice (Mertler 2016, pp. 14-15). The process follows a repeating cycle of four stages: planning, acting, developing and reflecting, as illustrated in (shown in Figure 30).

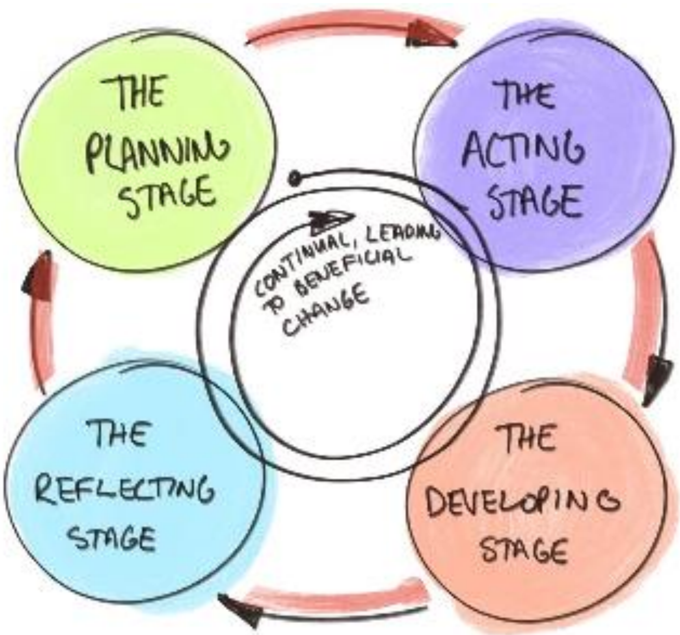

Figure 30: The four stages of the action research cycle (Figure by author, adapted from Mertler (2016, p. 17)

This is a cyclical process that can continue multiple times, with the goal of beneficial change being achieved during the process. One of the earliest mentions of Action Research was published in the 1950s in the Journal of Educational Research, where Stephen Corey (1954, p. 375) states:

> Action Research in education is research undertaken by practitioners in order that they may improve their practices. The people who actually teach children or supervise teachers or administer school systems attempt to solve their practical problems by using the methods of science. They accumulate evidence to define their problems more sharply […] They test out these promising procedures on the job, and again accumulate the best evidence they can of their effectiveness

Action Research in education can be understood as a structured form of inquiry carried out by educators or those directly involved in the learning environment. Its purpose is to explore how teaching takes place, how students respond to learning, and how classroom practices can be improved through reflection and evidence-based insight (Mills, cited by Mertler (2016, p. 4). Through engaging with Action Research educators are able to identify practical problems and actively work towards solving them. In the area of design higher education, many of the teaching is undertaken in studios using the methodology of Studio-Based Learning.

Studio-based learning

Studio-Based Learning (SBL) combines inquiry and apprenticeship methods, extending problem-based learning with a stronger focus on personal engagement (Brocato 2009, p. 139). It emphasises learning through action, where students think critically, adapt to challenges and develop lifelong learning skills (Kumar *et al.* 2021, p. 612).

SBL consists of students all working on their own design processes, while participating as part of a larger studio of learners who are all aiming to become practicing professionals. These students are within a physical studio space where learning takes place. The studio environment functions as a practical learning space equipped with the necessary tools, resources and guidance from experienced professionals (Brocato 2009, p. 140). Design projects that are undertaken within the studio are often formulated around a brief that replicates a real-world studio project, where the student works through various stages of the design process.

Within the studio, a student's own design process forms the core of their learning journey. The early stages typically involve proposing and exploring ideas through different forms of investigation and experimentation. Once initial concepts are developed, feedback becomes central, taking place through activities such as informal discussions, pin-ups, desk reviews and group critiques. This cycle of proposing, testing and refining reflects the essence of Studio-Based Learning, where understanding is built through action and the creation of a tangible design outcome (University of New South Wales 2025).

The stages within a Studio Based Learning project often compose of cycles of propose–critique–iterate where learners use feedback from others to refine their work (Brocato 2009, p. 139). This cyclic style repeats over and over, as one draws nearer to a resolved final outcome. A universally accepted design process can be unpacked as the Double Diamond which was developed by the Design Council, seen in Figure 31. It starts with Discovery, then Define, then Develop and lastly Deliver.

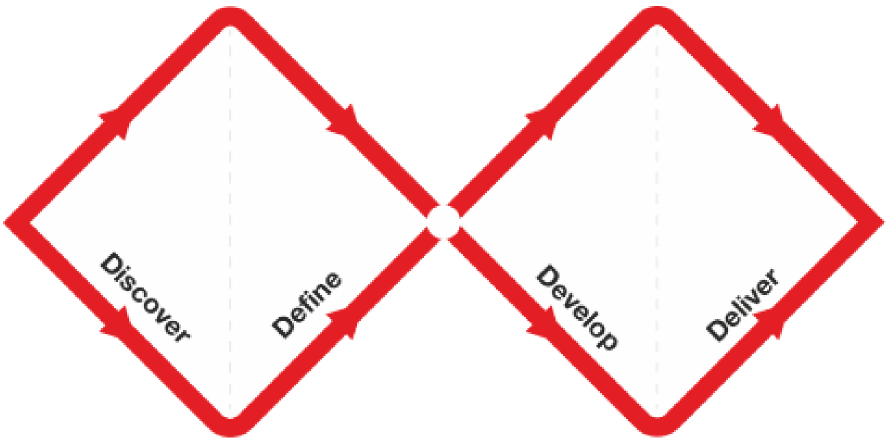

Figure 31: The four stages of the Double Diamond design process (Design Council 2025)

The first stage of the Double Diamond process aims to understand the problem by engaging with those directly affected. Insights from this exploration help redefine the design challenge. In the final stage, ideas are tested at a small scale, allowing weaker solutions to be discarded and stronger ones refined (Design Council 2025).

This entire process forms one iteration, which may result in multiple cycles of iteration, leading towards the delivery of a final suitable solution.

There are various approaches to teaching within the fields of Design, and many of these can be traced back to the Bauhaus, which operated between 1919 and 1933. Additionally, the educational approach titled Slöjd from Scandinavia teaches manual skills through woodworking and handicrafts practices, which has its early roots as far back as the 1840s. In reflecting on these two teaching approaches, guidelines for good practice can be understood.

Teaching in the Bauhaus

Within the Bauhaus, the use of workshops, not studios were to provide the basis for teaching. Apprentices were instructed and lead by 'masters' of each field, as well as fine artists. Masters would teach method and technique, whilst fine artists would 'introduce students to the mysteries of creativity and help them achieve a formal language of their own' (Whitford 2019, p. 30).

Walter Gropius, who founded and directed the Bauhaus from 1919 to 1928, viewed the workshops as experimental spaces where ideas could be tested through making. These environments encouraged the creation of prototypes that reflected contemporary needs, blending creative thinking with technical understanding (Whitford 2019**, p.** 206). Gropius aimed to develop designers who could move comfortably between artistic and industrial practice. Rather than competing with established industries or craftspeople, the Bauhaus worked alongside them, offering new possibilities for collaboration and innovation (Whitford 2019, pp. 206-207).

Teaching with the Slöjd approach

Originating in Finland during the 1860s, Slöjd was an educational approach centred on handcraft, encouraging learners to develop practical skills through materials such as wood, metal, leather, textiles and other traditional crafts (Sloyd & Croft 2025). The Slöjd method emphasised the importance of a dedicated "Slöjd-room", a studio environment designed to promote individual, hands-on learning where each student engages directly with materials and tools as part of the learning process (Salomon *et al.* 1892, pp. 18-21). This "studio" environment focuses on a core principle that each article shall be executed entirely by the individual worker and the teacher is not permitted to touch the work, which builds confidence with the learners. Within this dedicated *Slöjd-room*, every pupil should have a fixed place at their own bench. These benches were quite specific, with detailed descriptions of the workbench, including single and double benches, and extensive workholding capabilities (Salomon *et al.* 1892, pp. 62-64). The size of the benches were ergonomically suited for students to stand and comfortably execute the work. The Slöjd Handbook explains in great detail the ergonomic considerations for work being undertaken in the *Slöjd-room,* thus preventing muscular strain and preserve eyesight (Salomon *et al.* 1892, pp. 18-24). Tools, which were always to be of the best quality, were numbered for storage and identification, and had fixed places for storage, often organised in a Tool Cupboard. This meticulous organisation of the physical space was considered essential in order for cultivating habits of self-reliance, order, and accuracy in the pupils.

Personal reflection of studio teaching experience

In facilitating Studio-Based Learning processes, I would often deliver key activities and specific points throughout the process in an attempt to guide learners for the next step. This would be in the form of a lecture delivered to the students, with the utilisation of a presentation prepared on my laptop, projected to the front of the class. Students would be seated at their individual desks. This sometimes results in students becoming excited about forthcoming steps, but at other times they might remain unenthused. I generally invest much preparation into this stage of project guidance, as I feel a desire to share my passion for design and making with my learners. This has often, disappointingly, met with a lacklustre response, partly due to the manner in which I was relaying the content, and partly due to students being engaged ‘elsewhere’ on their digital devices. I often asked myself how to deliver the necessary content in a way that captured their attention, so that they could share in some of the excitement that I felt in the design process.

In understanding best practice within the practical learning environment as a space supporting learning, I decided to review my studio environments and identify areas of possible focus where better, more effective learning could take place.

Teaching methodology for product design

I use Action Research as a basis for my teaching, which offers the advantage of being a method of systematic enquiry that educators can undertake as researchers of their own practice (University of Missouri 2025). It is a cyclic process, allowing for steps to be taken towards successful realised beneficial change, led by the educator (Relay Graduate School of Education Library 2025).

Lin Norton has outlined a systematic approach to reassessing teaching methodology, in the 5 Steps listed below, known by the acronym ITDEM (2019, p. 70). It begins with (i)dentifying a specific issue or challenge within the learning environment, then (t)hinking about possible ways to address it. The next stage focuses on (d)oing it and implementing the chosen strategies, followed by (e)valuating the results. The final step involves using the findings to (m)odify future practice.

In my own practice I identified two focused problem areas, relating to the Studio Based Learning of manufacture technologies, which I wished to address through Action Research:

1. Teaching with sole reliance on digital presentations and projected images does not engage students and they are evidently uninterested and unable to relate to the content. Students often withdraw and only focus on their digital devices, and this is evidence of a complete disconnection from the lecturer’s teaching. The ultimate telltale sign is a student recessed back in their chair and having a nap, which is indicative that something has to change.
2. Teaching manufacturing technology in practical methods, to large groups of students can be very complex and dangerous to undertake. Industrial Machinery is very noisy, and dangerous, and students need to wear appropriate Personal Protection Equipment. This, coupled with the high cost of manufacturing materials and consumables, generates several hardships for introducing many different manufacturing approaches to students.

To address these problem areas, I decided to develop and implement certain interventions within the studio teaching environment (as discussed below) after which these interventions would be evaluated and assessed. This would allow for modifications to each intervention, with the intention to continue development towards a suitable method for engaging with the learners.

Discussion

Personal digital devices: positive and negative points

The devices were still evidently summoning the students into their limitless scrolling for entertainment. However, the students also use the devices positively, as a tool for photographic documentation as well as sometimes for note taking and timekeeping for timed tasks. The digital barrier formed by the device is often exacerbated by the wearing of over-the-head earphones where students choose not remove them whilst the lecturer conducts teaching. This is extremely problematic as it is unclear if the student can even hear what the lecturer is saying. The negative impacts on mental health, and the dependence on digital devices is a growing concern. University of Colorado Crisis Coordinator, Amber Johnston (2024) has noted that digital consumption has morphed into more than just negative consumption, and instead represents an overabundance of digesting content. The negative affects '*can increase or create: anxiety, sadness, uncertainly, a sense of overwhelm, fear, disappointment, discontentment, anger, feeling disconnected, depression, insomnia, jealousy, difficulties with interpersonal relationships and communication, OCD symptoms, and "Crazymaking"*' (Johnston 2024). I personally would prefer to leave all of this outside of the lecture studio and allow students to have a break from it whilst they are given the opportunity to actively engage in the learning I have prepared. I wish students would place their phones into a metal box upon entering the lecturing environment, and with them, any earphones that they may be carrying. However, as mentioned above, this would mean that they are not able to use the devices for the benefits of documenting, note taking, and timekeeping.

Manipulating the studio layout to encourage student engagement

As a millennial educator from a preceding generation, navigating the shift in student attention spans and preferred modes of engagement presents unique instructional considerations. The student's constant pull of digital notifications often competes directly with the immersive focus required for intentional studio-based learning activities. Students are at home sitting at their desks, staring at their digital devices, and they need to be removed from this setting in order to engage with the activity.

The physical separation of the students from their desks allows for this to be more actionable. At first I would rearrange standalone desks into one row at the front of the class, requesting the assistance of students to do this. The initial disruption forces students to leave their comfort zone and get to their feet. Arranging sufficient tables for the required items to be set up takes several minutes, and generally there are several students who quickly volunteer to assist.

Figure 32: Studio desks arranged in a linear pattern to allow for a collection of demonstration content (image by author)

Once the desks are arranged in a sequential pattern, students are much closer to the lecturer and engaged with the learning content. This is definitely a step in the right direction. A natural amphitheatre is formed with students seated on chairs behind the lower table, and those in the row behind them seated higher on the table surfaces (Figure 32). I am of the opinion that this is normal for a design studio environment, although I am not sure how normal it would be for other faculties. The lecturer is able to move along the length of the composed table, and demonstrate various examples of materials, tools, machines, showing how they may be relevant to the activity. This strategy worked very effectively for the early stages of a practical demonstration, but once students are encouraged to engage with the studio materials and equipment, the low desks (which are designed for one-sided seating) did not work that well, as the desks are too low for standing, and whilst seated, students on one side of the desk kept bumping their legs on the cross-members of that side of the table.

Intentional standing studio desk to draw students to the point of learning

If students are able to stand around raised desks it would allow for them to move more easily around the studio environment and drift in and out of the front positions. With reference to available standard steel and composite wood board measurements, I planned a suitable large studio standing workbench which was fabricated in the Departmental workshop by student tutors and Workshop Technicians. The overall dimensions of the bench tabletop are 2.75m long, by 0.9m wide. This is the exact size of one full-size wood board cut in half. This provides a suitable work surface for 10 to 12 students to all engage with equipment across the length of the table (Figure 33).

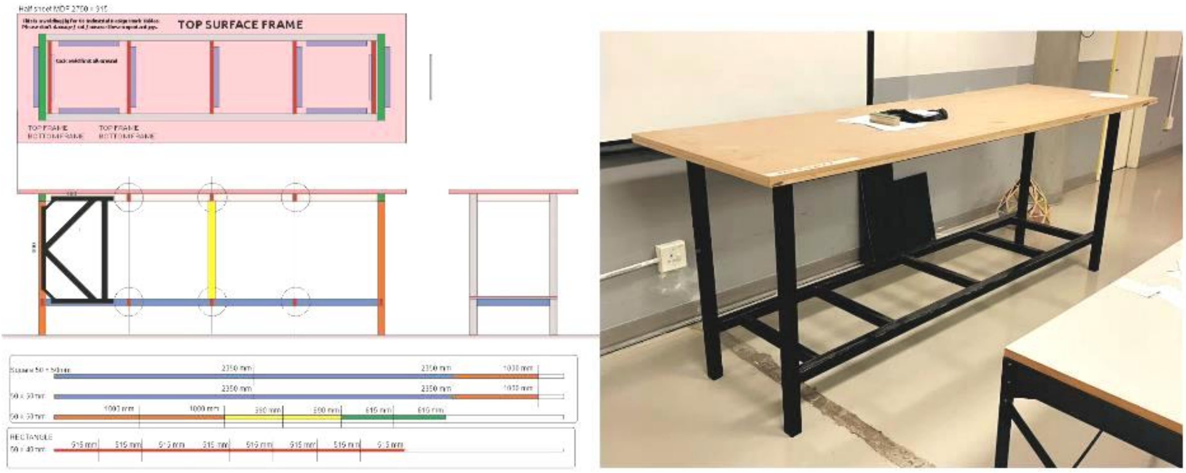

Figure 33: i custom designed work tables at a suitable height for standing students (image by author)

The height of the table was calculated to be slightly higher than wooden workshop benches, but lower than standing office desks. This was checked with short and tall male and female students, and the final height is 1.03m. Strong cross supports were added to allow for the storage of activity crates, or for students to rest their feet if they wish. The size and width of these tables meant they were able to be fabricated in the Departmental Welding Workshop and carried up and placed in the teaching venues. Two tables were fabricated as a pilot test, for two of the three undergraduate practical studios.

Leave your desk behind and stand on your own two feet

In an activity undertaken with students where the preparation included mixing and forming of materials into test swatches, students were able to engage with the learning materials and machines in a way that was more welcoming and user friendly. It is evident in Figure 34 that students are able to stand with comfortable posture, with the work surface at a suitable height for manipulating and engaging with the items across the work surface. This photograph was taken an hour into the activity, where they have already spent a fair amount of time ‘getting involved’ leading to this point, and the busy-ness of the activity is clearly evident.

Figure 34: With a higher desk, and allowing students to stand and interact with content around the desk, students can easily move in and out of a front-row position (image by author)

The standing desks allowed students to engage much more effectively with the learning activity. Being able to see students engage with the activity, talking with each other and working towards an outcome was extremely fulfilling for me, and I feel that engaged studio sessions are one of the most enjoyable aspects of teaching within the design field. It was messy, and the necessary items for effective clean-up have, until this point, not been a big concern to me. On wrapping up the activity, students were just as willing to assist with cleaning as long as the correct items were available, for example dust pan, cloths, and tubs for moving items to a suitable basin to be washed.

Preparation of content and supplies for studio-based learning

The most difficult part of preparing for an effective studio-based learning engagement, is trying to think of every single item that may be needed during the activity. This includes set-up, demonstration, hands-on activity, and post-activity steps such as cleanup and storage. Figure 6 is an attempt to map this visually. When utilising small machines in the studio, the machines must be checked to assess their readiness. A contingency plan is also a necessity, as relying solely on one machine may yield an unsuccessful activity if that machine fails. I had the unfortunate event of trying to carry a crate of supplies to a studio, where the only machine prototype slipped from atop the crate and fell to the floor, breaking one corner of the machine. I was extremely lucky that the function of the machine was not affected, as the rear corner broke, and not the functional motion components of the press.

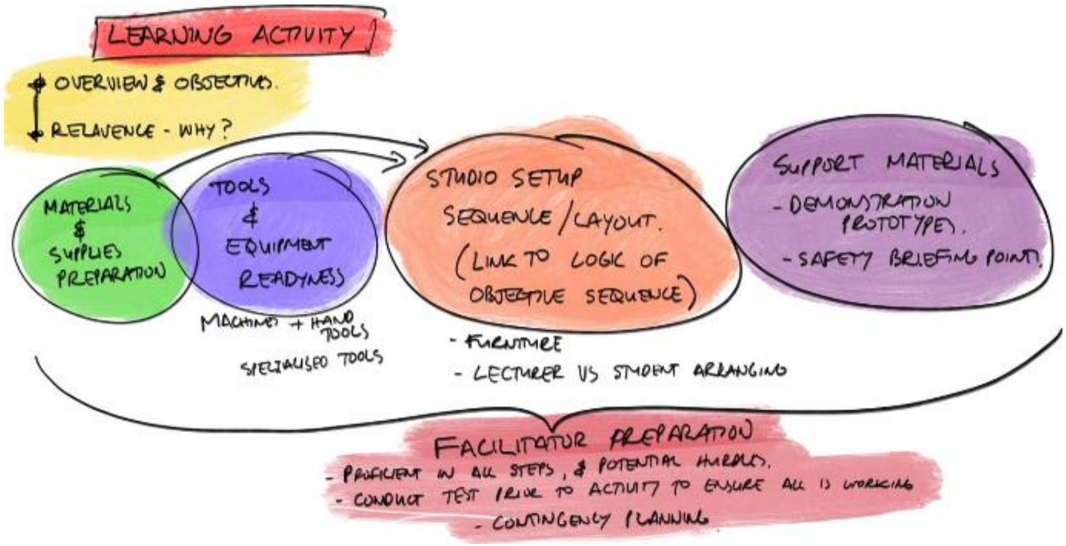

Figure 35: Preparation sequence for studio-based learning activity (image by author)

One needs to know exactly what materials, supplies, tools, consumables and support materials are needed. Once the activity starts, having a class full of learners waiting around whilst the lecturer forages to try and locate required items can very quickly lead to students losing interest as students can perceive this as a lack of preparation and commitment from the lecturer. When undertaking an activity I have a notepad or note taking app, that I use for the documenting the required equipment that will make the activity run smoother the next time.

Transportation and storage of growing collection of equipment and supplies

The transportation of all supplies to and from the studio also needed careful consideration, and stackable crates and a wheelable trolley soon became a necessity. Upon arriving at a planned studio activity, I would first ensure that the long studio table was in a suitable position, and if not in use was able to be placed alongside the wall. I would then place stackable plastic crates from the trolley onto the large worksurface. I would consider the sequence of teaching delivery, and what should be introduced to the students. I would start at one end of the table, and move along to the other end, placing items and components together in considered positions. For example, a process sequence would be introduced sequentially step by step, allowing students to understand how each element may be used when they engage it for themselves. The utilisation of support materials allows for students to see effective outcomes without having to wait for the entire manufacturing process to unfold, which can sometimes take several hours or days.

Manufacturing technology crates

A proposed solution to this, is the categorisation of required items into separate storage units which are latchable and include all supplies needed for said activity.

- What are the steps undertaken through the completion of the activity?
- What is required for each of the steps?
- Which elements of the activity are undertaken as Demonstration, Groupwork, or Individual?

The separation of different kinds of equipment and supplies into the following categories allow for storage crates to be prepared, stacked one on top of the other, and easily wheeled into the studio environment: 1: Machines, tools and equipment, 2: Consumables and supplies for a specific activity, 3: Support Materials and demonstration content, and 4: General Cleanup items. A mock-up image of this is illustrated in Figure 36, with an example of a hierarchy of different coloured labels assigned to the different functions of each crate.

Figure 36: Manufacturing technology activity crates (image by author)

These can be applied to the crates as an adhesive label (visible on the black plastic crate) or can be placed into specific label positions shown with the three thinner horizontal labels. An inventory list can be laminated and kept in each of the crates, and the lecturer must ensure that this list is checked in advance to allow sufficient time to purchase or collect any items which are not there and would be needed for a successful activity.

Next steps

The next step would be to evaluate the effectiveness of the crates within the studio environment and adjust the intervention as needs be. Additional tables need to be fabricated to allow for more student standing worksurfaces in the studios. I wish to prepare collections of Crates for the following materials and forming techniques.

- **Press forming** was the presented pilot activity and crate
- **Thermo-forming** of plastic components (press and line bending)
- **Extrusion** (of polymer clay, mimicking metal extrusion)
- **Material finishes** Including powder coating, electro plating.

My aim is ultimately to prepare different Manufacturing Technology crates for each of the different manufacturing approaches taught. This is to serve the studio learning of Material Forming processes of Plastics, Metals, Ceramics, Wood and Composites (Thompson 2007, pp. 10-17).

Conclusion

In an attempt to undertake Action Research within the Studio teaching environment, the development and utilisation of the custom tables have already proved to be valuable in allowing all students to engage more effectively for in-class activities. The accompanying categorised crates have not yet been tested within the studios, but will be undertaken soon. As with the cycles of Action and Reflection, this paper only documents the first iteration of this process. The intention is to continue to move forward towards ongoing student engagement, and a suitable and enhanced learning environment by evaluation, reflection and improvement after each project. By emphasising hands-on learning and in-class engagement, this paper provides insights into suitable approaches for studio planning, and lesson execution for effective learner engagement.

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