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# TEACHING PRODUCT DESIGN MORPHOLOGY: MATCHING EDUCATIONAL GOALS WITH AFFORDANCES OF DIGITAL TOOLS

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## ABSTRACT
Industrial designers use several kinds of representations to support reflection-in-action while developing design proposals. The affordances provided by digital tools impact the flow of shifting between different representations, thus influencing the ability for reflection and discussion. This fact challenges tutors who need to plan industrial design courses in digital learning environments.
This paper addresses planning a product design morphology course delivered in a digital learning environment in the context of problem-based learning. The study reflects upon the externalisation of knowledge and how it impacts the matching between educational goals, learning activities and the affordances of digital tools. Particularly the relationship between designing active learning experiences with conscious considerations of specific affordances provided by digital tools that students directly interact with. A reflection following the course delivery revisits the planning process and proposes a two-phase framework to consider overall and detailed pedagogical reasoning. The framework allows different levels of reflection towards designing learning activities by considering the use of the affordances of digital tools both in online learning environments and professional practice.

*Keywords: Affordances, online teaching, pedagogical reasoning, industrial design, external representations, reflective practice*

## 1 INTRODUCTION
The problem-based model is centred on the individual learner. The study activities contribute to empowering the learner in applying knowledge to solve real-world problems by using the ability to critically reflect on the problem, use appropriate resources, work in teams, and communicate effectively with others [1]. Such a definition finds commonalities with Schön's [2] postulation on the reflective practitioner, which is a cornerstone in industrial design reasoning. According to Schön, the process of designing, in which designers transform an ill-defined problem into a solution, is based on an ongoing reflection in action. The practitioner engages in both self-reflection on internal tacit knowledge, and externalisations of knowledge such as drawings, annotations, and verbal communication, and recalls previous experiences with similar or analogue situations to infer decisions on the project under development.
In online learning environments, access to different kinds of representation hinders design discussions. The flow of design discussions, where one makes use of different kinds of representations to communicate an idea or discuss a particular aspect, does not reach its full potential because of the affordances provided by digital tools and limitations of the medium. This fact poses challenges when designing online learning experiences, in particular in matching the educational goal, the goal of the task and the available affordances of digital tools [3]. Recent research [4] proposes that the educational goals and the decision-making process responsible for transforming the goals into pedagogical strategies for learning must be reconsidered before and during teaching in digital learning environments. In reconsidering the pedagogical strategies, educators must "have a systemic understanding of teaching content, teaching and learning processes, student needs, and dynamic characteristics of online environments to make appropriate instructional design decisions (i.e., transformations) for their pedagogy and teaching practices." To fulfil the systemic understanding of the educational goals Stephaniak et al. [4] propose a framework encompassing the planning of courses with the support of a)

external representations and b) the use of reflection-in-action to establish a solid foundation, followed by c) conjecturing strategies for the delivery. The authors conclude that the three-step framework enables better dynamic decision-making practices about technological challenges.

The case study presented in this paper details aspects that are proposed in Stephaniak’s study, but not specified. In particular, how affordances in digital learning environments are generally characterised as different from traditional learning [4, pp.2235-36]. I hypothesise that digital affordances can be further investigated if we break them down into steps that help students achieve certain educational sub-goals through specific tasks. In the present study, I present a case study that exemplifies the process of learning design in setting educational goals and learning activities and matching those to affordances provided by the online collaborative tool Miro.

In industrial design processes, externalisations of knowledge involve multiple outcomes that range from iconic representations, such as photos, sketches, 3D models or physical models to symbolic representations ones such as schemas, diagrams or textual annotations [5]. These externalisations are key to the process of idea development because they enable designers to elaborate on their ideas – from clarifying problems to maturing and testing potential solutions – and receive feedback from peers and tutors, that constitutes an important pedagogical strategy in engaging students in what Schön refers to as a “reflective conversation with the situation”. Kolko [6] highlights that “once externalized, the ideas become “real”–they become something that can be discussed, defined, embraced, or rejected by a number of people (…)”. The underlying notion is that easy access to documentation and an overview of the different kinds of representation may facilitate the reflection-in-action regarding implicit and explicit relationships that ultimately lead to better decision-making. Kolko states the importance of mapping these externalisations in a physical space to facilitate sensemaking. Even though such premise cannot be directly undertaken in digital learning environments, it can be emulated through affordances of digital tools.

This paper presents a case study on the development of a course in product design morphology that focuses on the relationship between technology and form. More specifically, in the process of transforming the educational goals into pedagogical strategies for online delivery. Product design morphology requires students to develop form-related aspects of a specific object and link those aspects to others such as materiality, manufacturing, meaning, and user interaction. Students must engage with an experimentation process encompassing the generation of multiple representations – that constitutes an important part of the learning experience – as means to externalise knowledge that can be reflected upon to evaluate overall aspects such as composition, proportions, configuration or meaning; and specific ones, such as the arrangement of components, joining and functionality of sub-assemblies or material choices.

By unravelling the process of matching educational goals and learning activities with specific affordances, this study aims to contribute to pedagogical reasoning in digital learning environments, particularly in the field of industrial design and problem-based learning.

# 2 COURSE STRUCTURE

## 2.1 The domains of technology and form

The pedagogical practice here described was addressed in the context of the course “Technology and Form”, 5 ECTS, in the MSc in Industrial Design at Aalborg University. The learning objectives were already established and were not changed. Overall, the knowledge, skills and competencies that students must accomplish by the end of the course focus on a) the development of advanced skills in the combination of technology in products or for producing products and b) visual understanding of form and composition in a product design for a given context. These educational goals are transformed into teachable subjects through a framework under which relationships between technology and form occur and directly impact industrial design practice.

The framework encompasses three domains: design, production, and paradigm. Design has outputs directly connected to production and both are set under a technological paradigm. The interplay across these three domains depends on multiple factors, however, in the context of the course, we focus on how the industrial designer can interpret technology development under at least one domain and explore it to create a product and associated design language that embodies a certain position towards the selected domain.

Regarding design, the development of computational technologies [7] is presented as enabling new possibilities for form generation and form evaluation. Production technologies are correlated with their impact on the design language of products in terms of technology pull or push [10]. The overall domain under which design and production occur is the technological paradigm [11]. In the context of the course, students are prompted into reflecting upon emerging paradigms of techno-social systems of production and consumption (e.g., distributed manufacturing, mass customisation, circular economy).

### 2.2 The assignment

Each student must design a multipurpose chair and conceptualise an offspring (which can be another type of seat, like a chaise lounge, armchair, bench, etc.) in the same design language. The chair should represent the student's interpretation of a potential future role of technology in the selected domain of design practice (design, production or paradigm).

The assignment development must accommodate two constraints. The first is the selection and reflection upon (at least) one domain to create the design brief for the chair development. The second is the use of a visual chair ontology [8, 9] in the design process for representing chair parts and its relationships.

The academic evaluation includes the submission of two posters and a paper reflecting on the process, and approach to technology under the selected domain.

Evbuomwan and co-authors [12] characterise three main models of design activity: prescriptive, descriptive, and computational. Prescriptive models analyse the overall design process and propose systematic steps to achieve the goals. Descriptive models characterise the designer's activities during the realisation of the design process. Computational models are concerned with the use of computational techniques to perform different activities throughout the design process.

In "Technology and Form" students develop their work based on a prescriptive model influenced by a computational model. The reflection document enables students to have an overview of the process, thus fulfilling the goal of descriptive models. The pedagogical goal is that students have direct experience with different models of design activity during the development of the practical part of the assignment, and the reflective document enables a post-experience analysis that consolidates the new experience and learning [13].

## 3 LEARNING DESIGN, EXTERNAL REPRESENTATIONS AND AFFORDANCES

*Table 1. Main affordances of digital tools in lectures and studios*

| Main affordances of digital tools | Learning activity | |
|---|---|---|
| | Lecture | Studio |
| Write | ● | ● |
| Upload images | ● | ● |
| Manipulate objects | ● | ● |
| Collaboration with peers | ● | ● |
| Zoom / Pan | | ● |
| Sketch | | ● |
| Establish visual relationships | | ● |
| Shift across other applications | | ● |

The learning design considers a dynamic unfolding of the overall educational goals and learning activities in sessions that includes lectures and studios. Lectures aim at introducing themes, terms and learning resources that can be further explored in the context of self-learning and encompass active learning methods that are student driven in order to allow them to relate the presented themes with their own practice (i.e., group discussions). Studios serve the purpose of enabling discussions about the work in progress and require students to prepare material beforehand. Studios allow for feedback from peers and tutor to prompt further reflection.

Overall, there are more lectures in the first half of the course and a progression towards studios and more student-driven activities as the course progresses. Each session of the course is structured by matching specific educational goals onto specific learning activities. Furthermore, the required affordances of digital tools were correlated with the type of learning activity, and who drives the activity (tutor or student). Table 1 summarises the main affordances of Miro to be used by students.

Writing, uploading images, moving text on the board, support the discussion activities in breakout rooms prompted by lectures. These affordances would be further used in studios, in addition to establishing visual relationships between areas of an image and a note, zooming into areas of an image, panning across different representations, colouring diagram nodes, sketching, and shifting between software applications to clarify specific techniques or procedures.

When considering the overall delivery of the course and the required affordances of digital tools, the affordances used in lectures enable a learning curve for students who have never used the tool, to have practical know-how of using such affordances, that will be used together with other affordances in studio activities (Table 1). This reasoning allowed for clarification of the strategies for delivering the course and the external representations to support it. In tutor-led activities, external representations encompass the design of templates on Miro for group discussions, for pinup sessions (Figure 1) and for the using the visual chair ontology, in addition to specific instructions on lecture slides.

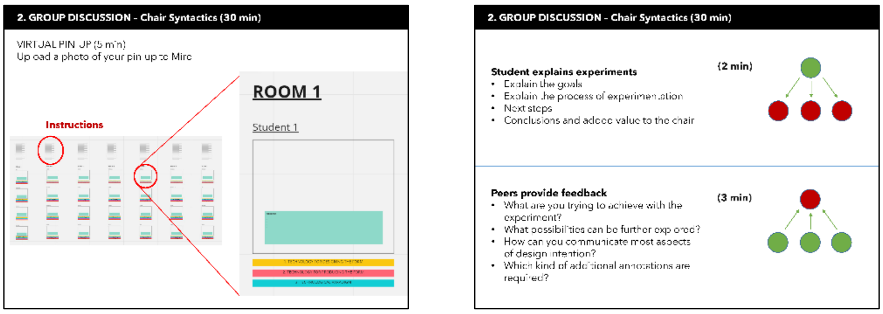


*Figure 1. Example of slides explaining how to use Miro templates in a studio session.*

Figure 1 shows external representations created by the tutor to be used in class. On the left slide the templates on Miro are shown organised into student groups and one is magnified for additional clarification of the task. The right slide details the task instructions, also shown on Miro.

The design of templates fulfils the goal of decreasing the need for changing fonts and sizes and organising elements, thereby providing a common structure that becomes recurring for each time the learning activity is pursued. The overall educational goal is that group discussions become a repository of information that can be revisited by students during the design process to facilitate reflection-in-action. Group discussion allows students to summarise to others what they have learnt, analysed, compare strategies, and relate to their previous experience, thus tackling the relational level of understanding [14] that can be then applied in problem-solving.

## 4 DISCUSSIONS

The case presented in this paper is positioned on problem-based learning theory [1], in considering the role of the tutor as a learning facilitator, of students as being responsible for self-directed learning, and in problem formulations that have ill-structured elements that act as drivers for student inquiry – in this case, the reflection about technology in a selected domain. The case focuses on a product morphology course addressing the relationship between technology and form, delivered online. The planning of activities encompassed external representations, reflection-in-action, and the conjecturing of strategies for the delivery based on affordances as defined by Stephaniak et al. [4]. Based on the experience of planning and delivering the course (one time online and two times hybrid), I consider that the planning phase of learning activities occurs under two phases summarised in Figure 2.

The first phase involves the overall interpretation of the educational goals into a rationale that is actionable from which conjectures can be formulated regarding how the educational goals will be translated into the overall course structure which includes the assignment, deliverables and sessions. External representations in this phase mainly consist of secondary data, annotations of potential ideas and matching those to educational goals and course structure. Reflection-in-action supports the refinement of the matching.

The second phase requires unfolding the previously established educational goals into sub-goals, and the course structure into: assignment phases and deliverables; sessions and types of learning activity;

the role of tutor and students in the learning activities; and a characterisation of the required affordances that students directly interact with. In this phase two types of external representations are produced: one that supports reflection-in-action for the tutor, and another that is designed for direct interaction with the student (e.g., Figure 1). The first type of external representations becomes crucial as multiple parameters must be assessed, and the role of the tutor and of the student must be situated in regard to guidance, feedback, critical thinking, problem-solving, etc. During this phase, these external representations and reflection-in-action enable different strategies to be defined and critically assessed, and potential problems to be addressed. This has a direct impact on the timeframe for the learning activity, and the need for strategies to reduce cognitive loads of students based on estimating the affordances of digital tools that will be subjected to direct interaction. This critical assessment leads to the development of the second type of external representations such as the design of templates, the use of similar elements throughout the collaborative online platform, and of instructions on the slides.

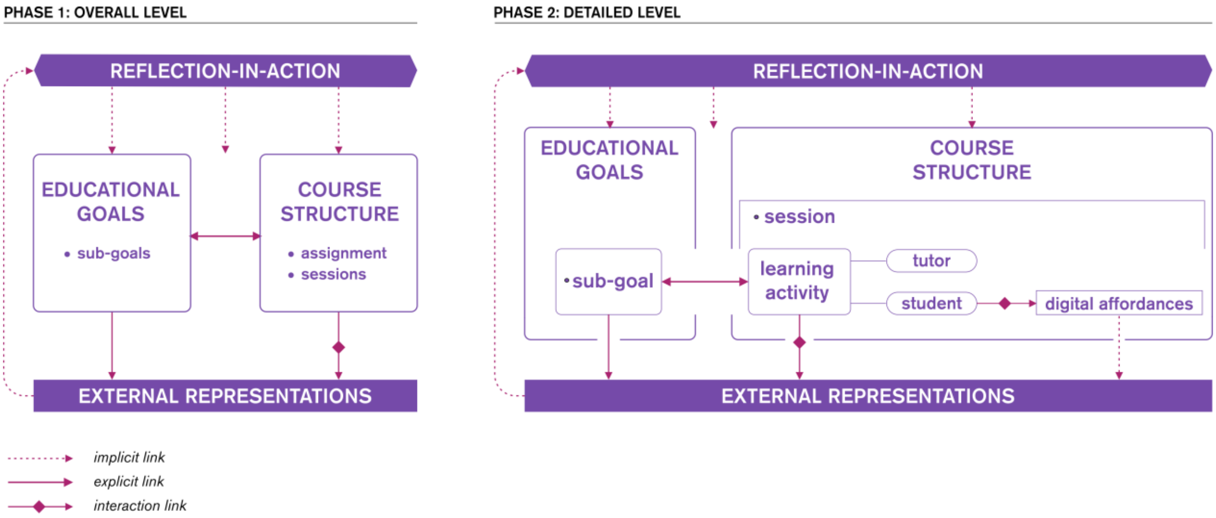


*Figure 2. Phases of planning activities for digital or/and hybrid learning environments by correlating educational goals, course structure and affordances of digital tools.*

This process of planning learning activities made me shift the focus to students as individual independent learners and find a different approach from upfront material that must be learnt and applied, to designing a set of activities that incrementally scaffold each other. These activities vary in their nature: some were presented in lectures, others in references for further reading, and others in peer-group discussions and practical tutorials. In writing the instructions for activities, I tried to be as clear as possible to minimise interpretation: by clarifying the level of difficulty of the task, by clarifying the output and how the output related to the assignment and industrial design practice. Together, these steps made me revisit the goals of the course several times, thus assessing the overall robustness of the course. To summarise, the goal is to create activities that students can use in self-directed and self-regulated ways in their learning; to find ways of being more explicit, how to trigger certain activities, or recap key points of complex activities; and to clearly define the minimum level of proficiency students must achieve to fulfil the educational goals.
The pedagogical challenge of addressing student engagement with online tools to externalise ideas in product development enabled me to break down the complexity of the design process for students into a set of phases, stages and series of steps to create a design proposal. This assessment was made together with the alignment between educational goals and assignment tasks. Designing activities that would activate knowledge transmission to students made me rethink my approach to teaching and engage in a deeper level of reflection about mechanisms to trigger self-regulated learning.
Based on this experience, I consider that the current digitalisation in higher education must address affordances with a higher level of detail, estimating how they can be used in digital or/and hybrid learning environments according to specific practices of the disciplines involved, in this case, industrial design. By focusing the discussion on affordances and not specific tools, we can estimate how these affordances contribute to the larger scope of the professional activity. As an example, in this course, the overview of the product provided by the use of the visual chair ontology during the design process, finds

similar principles of application in computer-aided design when setting up a parametric design model, or in rendering software when defining settings through nodes.

# 5 CONCLUSIONS

This paper presents a practical application of a conceptual framework that outlines the steps for assessing affordances in digital learning environments [4]. Building upon the practical application in the case study, I propose that the operational planning of activities should encompass two phases (Figure 2): one for overall alignment and one for detailing. During the detailing phase, the alignment of sub-goals with learning activities must consider the specific affordances offered by digital environments. Externalising the thought process through representations is key to supporting reflection-in-action. As a result, critical assessment guides decision-making for designing specific learning activities. This includes the development of strategies to minimise cognitive load for the identified affordances, such as creating templates or using analogies from other tools commonly used in professional practice for illustrative purposes. In the end, these strategies contribute to situating the affordances in a larger context of practice.

The planning of learning activities should include discussion with peers. The need to explain out loud the pairing between an educational goal, a learning activity and specific affordances leads to engaging in reflection about it. The feedback pushes reflection toward deeper levels of learning mechanisms, that support refinement prior to delivery. Moreover, it allows for discussing methods based on previous experiences from tutors, and thereby conceptualising new learning experiences.

Future work under the application of the proposed framework could assess the relationship between affordances, learning activities and motivation levels of students, in particular, if there is a change in the motivation level from the beginning to the end of the course.


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## REFERENCES


[1] Savery J. R. Overview of Problem-based Learning: Definitions and Distinctions. *Interdisciplinary Journal of Problem-Based Learning*, 2006, 1(1).

[2] Schön D. *The Reflective Practitioner: How Professionals Think in Action*, 1983 (Basic Books, New York).

[3] Bower B. Affordance analysis – matching learning tasks with learning technologies. *Educational Media International*, 2008, 45(1), 3-15.

[4] Stefaniak J., Luo T. and Xu M. Fostering pedagogical reasoning and dynamic decision-making practices: a conceptual framework to support learning design in a digital age. *Educational Technology Research and Development*, 2021, 69, 2225–2241.

[5] Hisarciklilar O. and Boujut J. F. Symbolic vs. iconic: How to support argumentative design discourse with 3D product representations. In *IDMME - Virtual Concept 2008*, Beijing, October 2008.

[6] Kolko J. Abductive Thinking and Sensemaking: the drivers of design synthesis, *Design Issues*, 2010, 26 (1), 15–28.

[7] Oxman R. Theory and design in the first digital age, *Design Studies*, 2006, 27(3), 229–264.

[8] *author.*

[9] Garcia S. A Computational Study on Form: a grammar-based tool for multipurpose chair design, 2018 (PhD Thesis, University of Lisbon).

[10] Verganti R. (2003), Design as brokering of languages: Innovation strategies in Italian firms. *Design Management Journal*, 2003,14, 34–42.

[11] Dosi G. Technological paradigms and technological trajectories: a suggested interpretation of the determinants and directions of technical change, *Research Policy*, 1982, 11(3), 147-162.

[12] Evbuomwan N. F. O., Sivaloganathan, S. and Jebb A. A Survey of Design Philosophies, Models, Methods and Systems. *Journal of Engineering Manufacture*, 1996, 210(4), 301–320.

[13] Kolb A. *Experiential learning: Experience as the source of learning and development*, 1984 (Prentice-Hall, New Jersey).

[14] Biggs J. What the Student Does: teaching for enhanced learning. *Higher Education Research & Development*, 1999, 18(1), 57-75.