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Connecting UD theory to tool selection in the design process

Tool use as theory implementation.

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Abstract: This article reports on a five-phase study into communicating Universal Design theory so as to align tool use to UD design outcomes. It explains how to apply a method for strengthening the connection between UD and implementation: design tools and the data they gather are that connection. This study builds on research indicating that designers lack explicit UD justification for design tool selection. The study describes a teaching method for UD that encourages students to actively consider what elements of a design problem require direct user-involvement and what tools might be appropriate to achieve this end. The study shows that the process of categorization and organization of those categories raises awareness of design tools generally and user-centred design tools in particular. The study also indicates that educators in UD and design generally should be concerned about the number and type of design tools their students are aware of and use.

Keywords: Universal design, design tools, Inclusive Design, design process, design theory

1. Introduction

The aim of this research is to explore how to strengthen the linkage between universal design (UD) practice and the theory on which it is based. It develops research into the relation of UD theory to its application, an issue raised by Herriott (2023). The significance of theory here lies in the relation between it and data needed to define a product´s specification. The theory and data are linked by the "instruments of inquiry", the design tool (Dalsgaard, 2017) though not only by the design tool. The theory guides which design tool and what data are to be gathered and what that data might mean. Ideally, these should be as strongly-connected as possible (Fawcett, 1978; Wacker, 1998, p.362; Swanson & Holton, 2005, p.8; Van Maanen et al. 2007, p.1145; Sileyew, 2019, p.28). The worst case is that data collection tools are arbitrarily chosen. This work aims to explore a teaching approach that strengthens the theory-to-practice link. This happens by reducing the arbitrariness of UD tool selection so it is driven by UD theory. The use cases are a) in a commercial setting and b) in a class-room setting. This work, as noted above, does not work on the assumption that the class-room is a full proxy for the commercial setting.

Universal Design (UD) is a conception of design for accessibility and disability which is rooted in US legislation originating in the 1960s (Ostroff, 2011). In the literature there is interchangeable use of the terms Design for All, Inclusive Design and Universal Design (Stephanidis, 2001; Ostroff, 2011, p.3; Heylighen & Bianchin 2013, p.93, Persson et al., 2015 p.2, Zhu et al., 2020, p.2). For this article the term UD is used.

"Inclusive design was first coined as a term to promote social inclusivity towards the ageing and disability population" write Zhu et al., (2020). The name UD dates from 1985 (D`Souza, 2004, p.1).

Related work has been carried out in the UK where the field is known as Inclusive Design (ID). UD combines a blend of consumer-orientated responsibility and rights-based thinking (Heylighen & Bianchin, 2013; Heylighen, 2014). Herriott (2011) and Bianchin & Heylighen (2017) describe UD's relationship to themes of social justice. The general objective of UD is to discover detailed information about the physical, cognitive and emotional needs of users. Heightened regard is paid to disability, neurodiversity, ageing and inclusion. This last point then is what the method described here is trying to focus on: to convey to the designer that a suite of tools is required which will aim to cover information gathering requirements in relation to emotions, cognition and physical capability. When the tools are actively selected rather than selected by intuition this results in products and services which work for users with capability loss but which also are functionally and emotionally acceptable to mainstream users. By "actively selected" is meant that the tools are chosen consciously and with intention e.g. "I will choose this type of tools in relation to UD theory in order to get a defined set of data".

Preliminary research (Herriott, 2023), as stated above, suggests that the link from theory to the use of tools is not strong. Further research by Herriott (2024) reports "that the instance of explicit tool use can be found in a minority of articles. Those that do have articulated links between the tool of inquiry and theory are classed into four groups, a minority of which are based on UD theory". This means that only a minority of articles relating to UD make it clear why the tools used were chosen. If the reasoning was not arbitrary it is not made clear why it was not so. To remedy this, one could consider ways to focus on trying to make tool-use more deliberate and less arbitrary, or in other words to *deliberately choose a design tool based on definite grounds*.

1.1. About design theory.

It would be helpful at this point to have a basic understanding of theory as it is understood in this text. A short conception of theory outlined in Martin (2010: 71):

> *"A theory is made up of a number of generalisations, some of them typically referring to unobserved things postulated because they make for the best overall theory, plus a number of observation statements, typically from a variety of different contexts, which confirm the theory, which are consistent with it and which are best explained by the theory".*

Jones & Gregor (2007, p.312) state that a design theory consists of: 1) purpose and scope; 2) constructs; 3) principles of form and function 4) artifact mutability, 5) testable propositions, 6) justificatory knowledge (kernel theories), 7) principles of implementation 8) expository instantiation. In this article, the interest is focused on principles of implementation in the case of the classroom project. Application in a commercial setting is discussed in the Section 7.

In a study into the incidence of theory in UD research Herriott (2024) found that discussion of theory tended to be incomplete with respect to Jones & Gregor´s (2007) criteria. Principles of form and function were not often expounded. Implementation (i.e., how to practice the principles) tended to be neglected. Testable propositions were difficult to identify; a significant number of studies did not offer any. Overall, the bridge from theory to practice was often implicit or not dealt with at all. This is the first point to bear in mind: the weak connection that links theory and practice.

1.2. Design Tools

I now turn to the second item of research which is a study of the use of design tools (Herriott, 2023). Dalsgaard (2017) provides the terms of reference for the concept of design tools. Herriott (2023) explored in greater detail the use of theory to support tools use. Tools selection and use is an important part of how the theory is implemented. The database for the 2023 study was a two-decades long series of conference papers (the Cambridge Workshop on Universal Access and Assistive Technology). A priori, the implementation of Universal Design theory would seem to require that use of design tools was explicitly discussed on the way towards uncovering the kind of information needed for UD outcomes. However, confounding that expectation, Herriott (2023) found that 55 of 242 papers named design tools. Just 7 of the 55 used Universal Design theory (and related fields) as the basis for the use of the tool. This is in line with Beck & Stolterman (2016) who found "the question of how theory is used in design research is underrepresented in the literature".

As noted at the start, this present article aims to explore how to connect theory to practice by making explicit the justification of the use of tools of inquiry. Its practical consequence is that designers and educators will choose the design tools for Universal Design with a basis in UD theory and in so doing choose more user-centred design tools.

2. UD Pedagogy – a short review

This section is a brief overview of the previous work relevant to this study and will consider UD pedagogy. There are three main areas in which such research into UD can be divided. Watchorn et al., (2013) and Scott et al., (2018) direct attention to what they call strategies. These explain in general terms the sequence of steps that can lead to a UD outcome, without detail of the connection from UD theory to the final learning result. Watchorn et al., (2013) dealt with the context of teaching UD for architecture: "Online and face-to-face teaching methods were employed, including virtual and real-life simulation activities designed to provide students with a personal experience of impairment." They didn´t make explicit how this related to UD theory. The strategies Scott et al. discuss are 1) using guidelines as a spur for creativity and 2) engaging users in the design process. This was a set of case studies with implicit not explicit connection from theory to the outcome via the tool selection and data gathering stages. Moving to the second area, Majuri et al., (2018), Persson et al., (2015)and Rieger & Rolfe, (2021) consider the frameworks that support the teaching. These items deal with how to approach larger or smaller classes (in terms of numbers of students) and the array of methods for on-line or in-class teaching. The essence of these is how to present a conceptual structure appropriate for a classes of different sizes. There is not much linkage to UD theory, but rather these consider different types of content and the delivery mechanisms for these. The third category is design tools and the use of these which concern authors Wilson et al., (2019); Dong, (2010); and Olesen et al., (2018). Wilson et al., (2019) performed a review of design tools used in some courses in the UK. Dong (2019) focused on the persona as a design tool. There was not a very large array of material to be found on the design tools which accords with work done by Herriott (2024).

Absent from this sample is evidence that there´s much interest in the link from theory to practice or, in other words, from theory to instantiation. Theory is generally partially presented in UD design research (Herriott, 2024). That part of it which is most often absent, following Jones & Gregor´s schema is also absent in the papers cited above. These paper have strengths to be sure but the link from theory to implementation is not one of them. This then leaves a gap to be

explored which then takes us to the research question in the next section. As mentioned earlier, this concerns strengthening the linkage between (UD) practice and the theory on which it is based. Thus in the literature section the UD pedagogy was discussed because the approach selected has involved teaching. The operational goals of the study were to see if awareness of user-centred design tools (a UD need) could be increased. The method is a strategic one (per Watchorn et al., 2013 and Scott et al., 2018). With reference to Majuri et al., (2018), Persson et al., (2015)and Rieger & Rolfe, (2021), the teaching has been adjusted regarding size of class and also it is all in-person and not on-line. The work is intended to find out about design tool awareness (an understudied area, as mentioned above). As such, the operational goals (finding out about design tool use with respect to UD) are aligned with the operational goals of the theoretical basis of the study.

2.1. Structure

The article is structured as follows. The next sections consist of the research question, the method, the data from five phases of experiments, the analysis and discussion. In terms of organisational framework, it is explained to the reader UD generally what design theory consists of (Jones & Gregor, 2007) and thereafter how design tools (Dalsgaard, 2017) relate to this. With that as a start point, the method is explained. The method involves experiments exploring how to encourage the linkage to tool use to theory to achieve a UD outcome. There are five of these, with each experiment (or "phase") showing data indicative of how students make more use of design tools and user-centred design tools.

3. Research Question

The concepts of theory (Jones & Gregor, 2007) in design and what a design tool are (Dalsgaard, 2017) were explained in section 1.1 and 1.2 The background to UD and UD pedagogy were explained in section 2. In this section is articulated the way in which theory, content and the framework align across the design process by testing a pedagogical approach. How can the use of design tools, which depend on principles of implementation (Jones & Gregor, 2007), be encouraged via interventions in the structure of a design process?

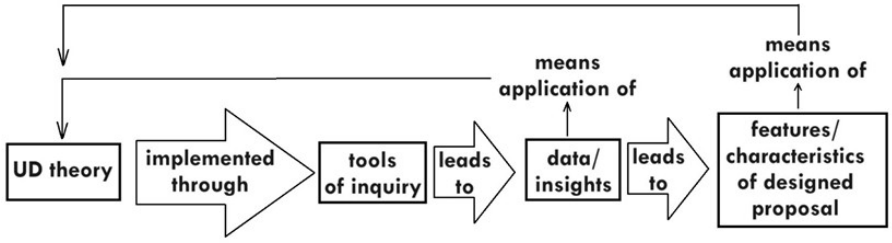
The hypothesis driving the research question is: the early identification, organizing and categorisation of the areas relevant to a design project will show where user involvement is required and which user-involvement design tools might be needed. The categorisation process involved indicating which topics required user involvement e.g. dimensions, usability. That supports the implementation of UD theory throughout the design process. Of interest is whether the identification and structuring of elements in a UD project improve designer´s awareness of which user-centred design tools to deploy in Universal Design projects. This was tested for in the class room-trials. This diagram (Fig. 1, below) represents the connection from theory to product features. Please notice the element "data/insights". To gather this data, the correct tools of inquiry are needed. The idea with this design method is to prime designers for which data types are required. The centre of this diagram is "tools of inquiry" (Dalsgaard, 2017)) which is why the experiments in sections 5.1 to 5.4 are focused on increasing awareness of tools in the UD design process.

Theory implementation depends on using design tools. Using design tools requires awareness of them. The study here proposes that recording students´ awareness is an indicator of the likelihood of using these tools. It is understood this is an imperfect measure but also it is not

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unreasonable to assume more awareness translates to some degree to some increase in the likelihood of the use of the tools.

Figure 1. The chain from theory to UD design features.



4. Methodology

The research question was formulated in Section 3 (above) and via this section the reader will move on to the experiments (5.1 to 5.4) guided by the methodology. Recall, as mentioned at the start, we are here seeing how to explore ways to strengthen the linkage between (UD) practice and UD theory. This is the theoretical bridge from the literature to the study: design tools represent implementation and the study focuses on implementation for which one needs awareness of the design tools and why they are chosen.

The methodological approach used here takes its cue from two elements. First is the general aim of UD, summarised as striving for a close fit between the broader mainstream of users´ physical, cognitive and emotional requirements and the product. This is to minimise design exclusion. The second is the set of design tools which could be used to gather and process information. We are focused on ensuring a through-line from theory to solution by implementation based on theory (Please see Fig. 1, above).

The class-room is the test environment in the following cases. One could have chosen a commercial setting also. But it is a complex environment and cross-comparisons would be difficult even if five different agencies could be found in time to complete the work. There are marked differences between the two settings so controlling the variables would be difficult. The experimental procedure described below this explores only ways to increase awareness students-as-designers within the framework of the pedagogical environment (please see Section 6 for more on this).

Recall that the literature (Herriott, 2024) showed that implementation of the theory was a weak point, namely that the use of tools and the reasoning for their use was lacking. This suggests that tool selection is not organised[1]. Given that a design tool is picked to get information, it would help to assess or scope in advance what the nature of the design case is so as to target the required information as comprehensively as possible. This then suggests that the method should support identifying the sub-parts of the design problem and which of these seem to need data related directly to the users.

The method used to scope the nature of the design cases (the class projects for the students) was derived from K/J Technique as described by Martin & Hanington (2009). In brief, the method

[1] For reasons of clarity and space, data itemizing which design tools were chosen in these experiments has been omitted. Generally, it showed that students chose from a narrow range of design tools chosen intuitively or, possibly, by default.

requires a group to name all the aspects of a situation they can think of, the pooling of the lists and the clustering of the groups into themes. In the revised versions (Phase 1 onwards) the participants are asked to identify which areas could require user-related data and what kind of data that is i.e. whether it is quantitative or qualitative. At the end of this process the students had a list of design categories that describe the task. This was divided into direct and indirect data gathering methods and general-purpose tools such as sketching and modelling.

The alternative to the collective way of identifying the categories of the design problem is either to not ask students to do this or to let them do it individually. If they did not undertake this task they would have missed a chance to identify user-related aspects of the problem. If they did it individually it would have reduced the opportunities to identify these aspects of the problem. A collective approach (the K-J approach) thus allows an opportunity to increase awareness of possible user-related issues to the largest extent allowed by the conditions.

Next, how to find out how aware of design tools the students were before and after? One approach would be to simply ask for a written list. That was rejected as it would be a list of out context of the process in which the design tools are embedded. Other approaches considered such as providing a menu or prompts might have artificially increased the number of tools names since people´s passive memory of such things is much larger than the active memory. Also, the students may have been inclined to check all the items listed at the start and at the end as was somehow expected of them. In the end, the method chosen was to ask for an annotated design-process diagram before and after the course.

Based on the model of Fig 1 (above), the steps in Table 1 (below) were followed to test how categorization and classification could support increased awareness of where user-centred design tools are be required. Students´ representations of the design process and tools used were compared before (Step 1) and after teaching (Step 6). The number and type of design tools were counted and compared before and after teaching. The teaching (not numbered) consisted of design lectures, supervision and project work.

Table 1. Stages in the Universal Design class teaching experiments. Step 5, naming a design tool also requires justification for its use: what the tool is and what information it gathers.

	Description	Comment
1	Visualising design process (“before”)	This is the first activity, prior to any teaching.
2	Universal Design Lecture, tools in design.	Theory and content of UD explained.
3	List of design concerns	Students make a list of the elements of the design problem
4	Grouped list of design concerns	Students organize the design concerns into themes.
5	Identify User-Related design issues	Students name a design tool to be used to gather the necessary information to tackle the design issue.
-	Teaching, supervision and project work.	
6	Visualise design process (“after”)	Students produce another diagram of their design process

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The following sections examine varying approaches to relating UD theory to the tools to be used. The five experiments were as follows. In the preliminary trial, the process was developed and adjusted in class. For Phase 1, it was refined and tested on a larger class (42 students). Students had project work between the preparation of the "before" and "after" diagram. Phases 2 and 3 produced more data and the procedure stabilised.

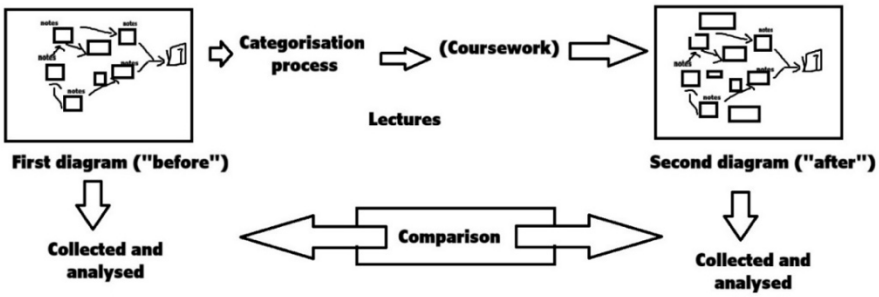
Table 2. The five stages of the experiments. In the table below the term "AC" means "accessory design". "ID" means "industrial design".

	Course name	Discipline	Tuition format	Year	Location	Date
Preliminary	Tools	ID and AC	Full length	BA-1	Denmark	Spring 2023
Phase 1	Transport Design	ID	Full length	BA-3	Turkey	Autumn 2023
Phase 2	Universal Design	ID	Full length	BA-2	Denmark	Spring 2024
Phase 3	Tools	ID	Full length	BA-1	Denmark	Spring 2024
Phase 4	Design Perspectives	ID, Clothing, Textiles, Communication	Short	MA-1	Denmark	Autumn 2024

The short version, (Phase 4 on Table 2) of the experiment explored what the effect would be of lectures on their own, without course work. The students heard about UD theory and about user-centred design tools. They were asked to consider their own previous work rather than a new project.

In all phases the students drew a design process diagram before other tuition and project work and then drew a second diagram at the very end of the course. The "before" diagram-drawing makes a baseline for the participants´ general awareness of user-centred design. The "after" diagram is a means to assess the student´s awareness of user-centred design tools after they have finished their project. Fig. 2 (above) shows the process in a simple form.

Figure 2. The experimental process (generic). Note: This diagram represents how students were asked before teaching to draw a design process diagram which was compared to a process diagram drawn at the end of course. The second diagram was expected to show increased awareness of user-centred design tools.



The process of analysing the data involved recording all design tools named on the *Before* and *After* process diagrams. Other approaches could have been doing qualitative interviews before and after the course. The pros and cons of qualitative approaches are discussed by Zawawi (2007) and Goertz & Mahoney (2013) among others. In this case, it was considered desirable to

focus on quantitative data for its immediacy while being aware of the missing subjective and interpretational richness provided by qualitative approaches. Students were not asked to provide a justification at any point in the process. The method (as explained) involved checking awareness of tools before and after. This is, to repeat, not a qualitative methods experiment. The author is also aware that some interpretation of the terms used by the subjects was involved. Other work using the same method (Herriott & Jackson, 2025) indicated the reliability of the process in terms of intersubjective agreement of interpretation of the analysis.

Now that the research question has been described (Section 3) and the method discussed, the next step is to look at the data from the experiments. Recall that, in terms of the organisational framework, the interest is in how to raise awareness of and increase use of design tools to gather user-related data to improve the UD outcome.

5. Data

The following tables show the results of the classroom experiments. The data consisted of the design tools named and recorded in the “before” and “after” process diagrams. Each participant submitted a numbered A3 sheet. The student used the same number for the “before” and “after” diagrams so they could be matched and compared.

The design process diagrams were collected after each phase. Instances of design tools were recorded. Instance of user-orientated design tools were noted. These included ideation, sketching, prototyping, modelling, mind-maps, brainstorming and CAD modelling, mood-boards, CMF boards. User-centred information gathering tools included interviews, focus groups, user-testing, questionnaires, co-creating, “co-design”. Some interpretation is required since there was not an agreed list of design tools and students appear to find it difficult to distinguish between tools and methods, as it seems that many researchers also do (Herriott & Akoglu, 2020).

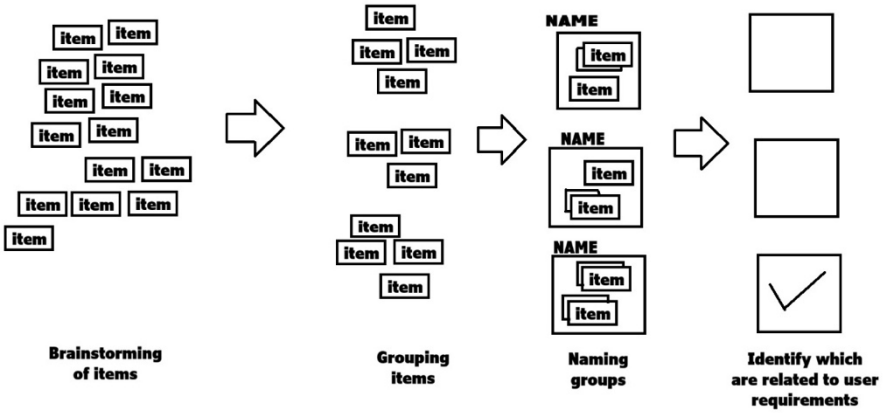
5.1. Phase Zero: BA-1 ID and accessory design (AC) students, Denmark

The class consisted of first year BA ID and accessory design (AC) students. It was a course on hand-held tool design The categorization process ran using a modified version of the K-J Technique (Martin and Hanington, 2009). The categorization process started as a class exercise with all students working in groups to identify the individual elements of which the design problem might consist. The collected list was organized in class and grouped into categories. These might be material, usability, functions, form-giving. The categories were divided into ones in which user data was required. This was further divided into those where indirect data would suffice and where direct user contact was required. An example of indirect user involvement data would be ergonomic data sheets or market research. An example of direct user involvement would be an interview, ethnography, or a focus group. Other tools such as drawing, analogue and CAD modelling and mood-boards were also identified. The process is shown schematically in Fig. 3 (below):

There were eleven diagrams collected and analysed for this phase. In the pre-course diagram, the average number of tools cited was 4.45 per person, skewed somewhat by Student #2 who listed 14. The average number of identified user-orientated tools was 1.5. The average ratio of user-related tools to general tools per person was 0.32 (the number of user-related tools divided by the total number of tools listed in each response). Martin & Hanington (2009) list 100 tools of

which 34 are user-centred. The ratio here of all tools to user-centred tools is thus 0.34, which is a point of reference for a ratio of user-centred design tools to all tools.

Figure 3. Left to right: naming design issues, grouping, naming the groups, identifying where user-centred design tools are need. Note: This diagram shows how, from left to right, students thought of elements that would be involved in their design project, then grouped those elements, named those groups and then identified which groups were related to getting user requirement data.



Six of the eleven responses did not list *any* design tools but did offer clear indications of a design process expressed in other terms. Those were, for example, a flow-chart with yes-no decision nodes or statements of the information required e.g. material, functions. The conclusion reached from this "before" diagram was that students were not very much integrating design tools into their conception of the design process. Usability/accessibility could not be said to be a strong element of their understanding given that under a quarter of the few tools named involved gathering information about the users.

In the "after" phase four weeks later, the average number of tools cited was 4.7 per person. The average number of identified user-orientated tools was 2.09. The average ratio of user-related tools to general tools per person increased to 0.51. The following table (Table 3, below) summarises the change in awareness of user-centred data gathering tools from this group.

Table 3. Preliminary Phase Zero. Industrial Design & Accessory Design BA-1 students, Denmark. Spring 2023.

	Named Any tools %	Named a user-related tool %	Average of all tools named (A)	Average no. of user-centred tools named (B)	Ratio of all tools to user-centred tools (B/A)
Before	81	63	4.36	1.6	0.36
After	100	81	4.72	2.27	0.48

5.2. Phase 1: 3rd Year ID students, Turkey.

The students were 3rd year industrial design students. The first activity of the class was to ask them to visualise a design process, bearing in mind the project they had started. That involved charging stations for electric vehicles. The class then had a four-hour tutorial during which they received a lecture on Universal Design and instruction on tools used to gather data in design. The next phase required the class to list the design concerns inherent in the project. The class had just finished their initial survey of the task as poster presentations. In the next phase class members were asked to list the design concerns for the entire class. This created a collective list of approximately forty areas of interest e.g. ergonomics, material selection, safety, graphics,

accessibility. The class were asked to individually turn this list into a set of clusters of related items. Penultimately, the class had to identify those areas on the clusters which required direct user involvement and what design tool might be appropriate to obtain that information or process it. Finally, the class were asked to draw a new diagram of the design process they envisioned would lead to a satisfactory design outcome. The students received 1:1 feedback during this work and, in particular, were encouraged to see the visualization of the diagram as a means to explain to a third party how this project would be completed. Having primed the students about a) design tools, b) user-centred design and c) Universal Design, the number of students who cited design tools increased and more of the tools required user involvement.

Table 4. Product Design (Transport Design course), BA 3 students, Turkey. Autumn 2023

	Named any tools %	Named a user related tool (%)	Avg. no. of all tools named (A)	Avg. no. of user-centred tools named (B)	Ratio of all tools to user-centred tools (B/A)
Before	89	30.7	3.26	0.41	0.126
After	91	78	6.65	2.51	0.377

The data is summarised in Table 4 (above). Awareness of any design tools increased to a little over 9 in 10 students. The number of students who named a user related tool reached nearly 80%, up from 30%. The number of tools named approximately doubled but there was a marked increase in the awareness of user-centred tools, from under 1 per person to 2.5 per person. So, general tool awareness went up but user-centred tool awareness increased even more (rather than increasing by the same amount).

5.3. Phase 2: B-ID 2 Universal Design course, Spring 2024, Denmark

The class consisted of 2nd year bachelor students, a course about Universal Design which ran over four weeks. The class size was 17 students. In the first diagram, before tuition, the average number of all tools named was 4.69 and the average number of user-related design tools was 1.8. At the end of the course (with only 10 students available to do a diagram), the average of all tools named was 7.2 per person and the number of user-related tools rose to 2.9 person. See Table 5 (below)

Table 5. B-ID 2 Universal Design, Spring 2024.

	Named any tools %	Named a user-related tool %	Avg. no. of all tools named (A)	Average no. of user-centred tools named (b)	Ratio of all tools to user-centred tools (B/A)
Before	93	75	4.69	1.8	0.33
After	100	100	7.20	2.9	0.40

In this iteration awareness of user-related tools increased from a high level, 75%, to 100%. The number of user-centered tools increased from 1.8 to an average of 2.9 per person. The ratio of all tools to user-centered tools increased but the difference was less than in the previous round.

5.4. Phase 3. "Tools" course. BA ID-1 students Denmark, Spring 2024.

This phase involved a class of 17 first year BA students. The course involved designing a hand-tool and also involved explicit instruction on Universal Design and the concept of user-centred design

tools. The categorization process was repeated. The course resulted in design proposals for hand tools including CMF, sketches, analogue and digital models. It ran for four weeks. The data is summarised in Table 6 (below).

Table 6. BA-ID 2 "Tools " course, Spring 2024.

	Named any tools (%)	Named a user-related tool (%)	Avg. no. of all tools named (A)	Avg. no. of user-centred tools named (B)	Ratio of all tools to user-centred tools (B/A)
Before	87.5	81	4.06	1.93	0.48
After	100	100	8.62	4.07	0.472

There was an initial high general awareness of tools reaching 100% in the "after" diagram. The number of tools cited doubled as did the number of user-centred tools. The ratio of all tools to user-centred tools was approximately the same (a very slight drop) which is more likely noise than signal.

5.5. Phase 4: MA-1, Design Perspectives, Autumn, 2024

The last part of the study, Phase 4, consisted of newly started first semester MA students on an introductory course called Design Perspectives. The students were from industrial design, accessory, fashion, communication and textiles lines. This version featured a shorter, half day lecture on UD. The project they carried out was not a UD project (meaning a UD project was optional). The course did have a strong focus on user-understanding and was aimed to promote equitable outcomes in a social design context. The students did not conduct the categorization exercise. So, they did receive UD tuition (lectures) but did not do the categorisation exercise that establishes where user-centred information is required. The data is summarised in Table 7 (below).

Table 7. MA-1, Design Perspectives, Autumn, 2024

	Named Any tools %	Named a user-related tool	Average number of all tools named	Average number of user-centred tools named	Ratio of all tools to user centred tools
Before	53	26	1.73	0.733	0.42
After	67	66	3.93	2.07	0.53

Before the tutorial, 53% of the class named one or more tools in their visualization. This increased to 67% after the tutorial. Before the tutorial, 26% named user-related tools which rose to 66% after the tutorial. Before the tutorial, the average number of all types of tools named was 1.733, skewed by student 15 who named 9. This rose to 3.93 after the tutorial. The average number of user-centred tools named per student was 2.07. The ratio of all tools to user-centred design tools increased by a fifth but the absolute average number was just over 2 per student.

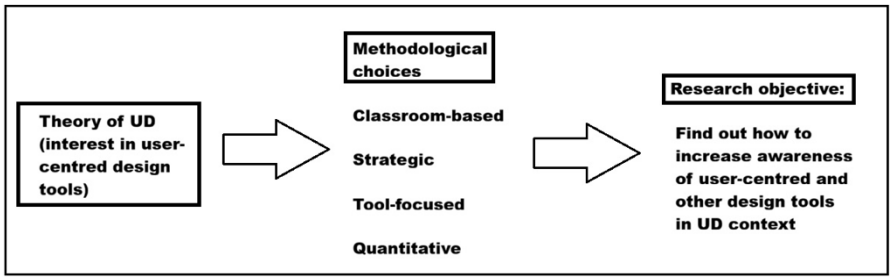
Regarding the organisation of this research, the reader has now been appraised of design theory, tools in design and the concept of UD. The studies have generated data showing how the awareness and therefore use of design tools was affected by different teaching approaches. In very general terms, these approaches to slightly varying degrees show increased awareness of design tools to gather data about the user so as to achieve UD design goals. The data is analysed below.

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6. Analysis

One question that must be briefly addressed is how the literature review covered in section 2 are related to the findings. The findings indicate a change in awareness in design tools and also add to the knowledge of strategic approaches discussed by Watchorn et al., (2013) and Scott et al., (2018). The findings also show how the conceptual work done by Jones & Gregor (2007) and Dalsgaard are translated into practical actions regarding design tool use. See Fig. 4 (below).

Figure 4. The diagram summarises the flow (left to right) from theory to research objective via methodological choices.



From a use case perspective, this process has been about seeing how the use case had demonstrated methodological feasibility. "A use case is an artifact that defines a sequence of actions that yields an observable result of value" (IBM, 2025). The sequence of actions was to use a categorisation process pooling participants´ knowledge so as to boost their ability to think about a design problem in terms of sub-tasks. This was the basis for identifying which areas would require user-centred information. And then this led to the question of what design tools would be needed to get that information. The effectiveness of the categorisation process was compared with an instance of only giving tuition (the final phase). The increase in the number of user-centred design tools was the smallest and the number of such named after tuition was the lowest.

Table 8: Summary of the change in awareness of user-centred design tools

Phase	Class	Named a user-related tool – before %	Named a user-related tool- after %
Preliminary	BA – 1 tools	63	81
1. Full prep.	BA – 3 Transport Design	30.7	78
2. Full prep	BA-2 Universal Design	75	100
3. Full Prep	BA – 1 Tools	81	100
4. No categorisation	MA 1 – Empathy & Equity	26	66

This is the summary (Table 8, above) of the changes in awareness of user-centred design tools in the five phases of the experiment.

Phase 4, without the categorization and without the design tools discussion ended with the lowest final awareness of user-centred design tools. If the application of UD theory depends on a fine-grained approach to data gathering then getting designers aware of the tools is a good start

to achieving a UD end. Categorisation and linkage to probable design tools would seem to support this.

Another point to discuss is that the qualitative data changed in the course of the experiments. Initial "before" diagrams tended more to be impressionistic e.g. abstract representations resembling the famous fuzzy-front end of Sanders & Stappers (2008). The "after" diagrams tended to be more structured and formalized, indicating that the student was representing something that they had done and in a way more communicable to others.

In general, there was very little change in the *diversity* of design tools named, of both types. Students tended to repeat the same tools rather than add new and different ones to the list. The inventory of design tools cited by students was not large. Ideation, sketching, prototyping, modelling, mind-maps, brainstorming and CAD modelling, mood-boards, CMF boards and the nebulous "desk research" were be the most frequently named. User-centred information gathering tools included interviews, focus groups, user-testing, questionnaires, co-creating, co-design (without further explanation), and observation. Role-play and "ergonomic data" were also named. Martin & Hanington (2009) list 100 tools for tackling design problems. There is a rich literature of design-tools created for UD. Herriott (2023) found 53 listed among the CWUAAT series of conferences papers. Almost none of them are cited by the participants in these investigations, whether or not there was accompanying literature to support the course.

Not unexpectedly, the group that received the least tuition and which did not do a project showed the least change, though also starting from a surprisingly small base. In mitigation, the Phase 4 participants on the MA design course had only started the first week of the first term and may have been "rusty" after a summer holidays. We can consider the Phase 4 as the baseline for what happens if one presents the theory of UD and no other tuition: awareness increases in the form of being able to cite a greater number of user-centred design tools but not by as much as when there is the categorization exercise.

7. Conclusion

The aim of this research, as stated at the start, was exploring how to strengthen the linkage between universal design (UD) practice and the theory on which it is based. The linkage was the use of design tools to gather qualitative and quantitative data. A bluntly formulated finding is that if one wants to teach UD, the students must understand the core idea of gathering detailed, fine-grained user data:

> *more user-centred tools, more often, more of the time, and chosen with justification.*

In section 4 I discussed the choice between a class-room or commercial setting. It would be highly interesting to see how to implement any aspect of this model under the rigorous conditions of a commercial setting. A priori, one might not have high hopes for much success. What one can hope is that the method described can at least encourage less opportunistic and intuition-based selection of design tools when the students find their seat in the design workplace.

The results here show improvements in the proxy for awareness. This means instances of user-centred design tools named increased but less than might be hoped for. One needs to do more than 1) explain the theory of UD, 2) carry out categorization processes and identify where user-centred data is required, 3) explain the value and use of design tools and also 4) run a design

project. Together these do raise awareness of design tools including user-centred design tools. They result in project work that is demonstrably UD in intention and outcome.

However, cause for concern remains. One is that three out of five times the awareness of the tools did not reach 100% despite explicit instruction. The last instance, of course, left out the coursework and categorization; basic tuition on UD alone does have some effect. But categorisation seems to increase awareness further.

Clearly, something more is needed to ensure that not only do students internalize the basic idea of more intensive user-centred tool use but can also show a raised awareness of the *variety* of design tools available. Note that the Hanington & Martin (2009) reference was listed as course material for Phases 0-4. Copies of the book were brought into the classroom and the contents discussed as a class exercise. Despite the evident value of this resource generally, and with regard to UD, the participants seemed not to reach for this book in the course of their project. One might have expected that explicitly and loudly highlighting the use of tools needed to get fine-grained data might have been a sufficient prompt to explore options beyond the standard menu of design tools. Apparently not.

Further work on this could involve analysing the projects that result from the teaching. It could be useful to compare this with a "standard" UD course. It might be possible to conduct interviews with students to examine what they mean by the diagrams they produce. Additionally, for UD courses, a way needs to be found to encourage critical engagement with design tools´ relation to UD theory. How this might be done is the next step in this research. At present the work shows that an assumed proxy for the awareness of UD theory has shown some change. Whether the students consciously link the tools to the theory requires further inquiry.

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AI disclosure. No AI was used in any way for any part of the creation of this document, including internet searches. AI use is antithetical to the goals of just and equitable society. There is no "reasonable use" of these tools as they depend on exploitation of labour and resources.

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