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EVALUATION OF WORKBOOKS AS AN ACTIVE LEARNING TOOL FOR INDUSTRIAL DESIGN ENGINEERING

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ABSTRACT
Industrial design engineering combines technical rationality and reflective practice, to support students' reflection on their design process a workbook approach has been developed. The workbook approach guides students to reflect on open-ended design projects through cycles of reflections. A typical workbook consists of both written text, i.e., literature reviews and methods employed, and sketches and photos illustrating the process and its results. The workbook approach is currently implemented in five compulsory and several elective courses at Industrial Design Engineering (IDE). During 2020-22 a project was performed to evaluate the implementation of workbooks and get feedback from both active students, alumni and the faculty. Results show that workbooks support students' self-regulated learning, and the workbook's guided reflection is a valuable tool for reaching higher levels of learning in design. However, it seems that there is a need for a workbook framework to support both teachers and students in how to use the workbooks throughout the programme.

Keywords: Workbooks, active learning, self-regulated learning, industrial design engineering, design thinking

1 INTRODUCTION
This paper focuses on the workbook implementation at the Industrial Design Engineering programme (IDE) at Luleå University of Technology, Sweden. A workbook approach is a tool for supporting active and self-regulated learning, reflection-in- and -on-action, allowing for teachers to guide students into doing certain tasks, and providing clear goals in otherwise rather open-ended design projects. The idea of the workbook approach is for students to employ goal setting and performance evaluation, hence a self-regulated learning strategy. It supports students in embarking on design projects in more informed ways. IDE is unique compared to other engineering educations as it combines both artistic and scientific approaches and practices, it combines technical rationality and reflective practice. Typical design projects address the social, economic, cultural, material and technical dimensions of a situation in iterative design thinking cycles of gaining empathy for user needs, visualising and materialising ideas and concepts and testing with users to inform the process. The workbook approach is a tool to guide such open-ended projects through cycles of reflection in- and on- actions.

1.1 Active and self-regulated learning
In brief, active and self-regulated learning deals with how students learn. One aspect of this is the surface versus the deep-level approach to learning [1]. The surface approach involves more descriptive accounts of action versus the deep-level approach that involves more understanding the basics and applying them in a certain context. Neither of these strategies is individual student constructs. Rather, they depend on other students' and teachers' knowledge and prior experiences forming a certain educational culture [2, 3]. Self-regulated learning involves how teachers interact with students in learning activities and how they impact and organise students' education in different ways [4]. The focus is on providing motivation, formative feedback, clarifying responsibilities, and supporting reflection and self-guidance. Students who apply self-regulated learning strategies actively search for information and try things to master a task or subject. They develop their self-regulated strategies to recognise that their performance is worth the effort [5]. This requires an educational culture that promotes students to take their own initiatives

and actively discuss each other's understandings, ideas, concepts, or other expressions. Part of such culture is teachers' flexibility, to be able to interpret students' initiative even if it wasn't exactly what the teacher had in mind and respond to what the student has thought and acted upon [6]. Then students will see that the investment paid off and are more likely to apply similar strategies in upcoming tasks.
A coached reflection can support the previously mentioned self-regulated learning strategies during learning activities [7]. Historically, Dewey restated the relation between reflective thinking and the educative process [8], drawing on the ideas of renowned thinkers such as Plato, Aristoteles, Confucius, and others. Further building on Dewey's work, Schön coined the concepts of reflection-in- and -on-action some forty years ago [9]. Unstructured reflection involves the kind of thinking that happens when faced with unique and perplexing challenges. This means simultaneous reflection and doing, implying that the student has reached a stage where they can think meaningfully about what is going on. It involves criticising, restructuring and testing understandings and experiences. Such on-the-spot reflections can make a difference to the immediate situation at hand, for example, the student realises something and can change accordingly. Coached reflection-on-action, on the other hand, involves making students re-think or look back at an experience to identify what they learned about it [7, 9]. Teachers can support a learning process in which students use different levels of reflection [10].
This can also be encouraged over an extended period to nurture a culture of reflection to develop active and self-regulated learning strategies. Reflection can be related to formative and summative assessments [11]. A formative assessment providing students with feedback on something before the final examination is more likely to make the students reflect on what they have done and how they might improve it. Such formative feedback can support reflection through questions that aim for deepening or widen students' understanding of a particular situation. Also, self-assessment is described as the evaluation or judgement of the worth of one's performance and identifying strengths and weaknesses to improve learning outcomes [12]. It is recommended that self-assessment involve students creating something that requires higher levels of thinking, disciplined inquiry within a specific discipline, and that the assessment is transparent and that the assignment has opportunities for feedback and revision during the task [13]. Motivation for various kinds of self-assessment is that it increases students' engagement, interest, and attention, and it provides information that is otherwise not easily accessed, for example, such as time and effort spent on task.

1.2 Workbooks and portfolios

Design communities often use portfolios for presenting samples of work performed [14]. Typically, portfolios reflect a designer's best work and present the final design, the artefact, and not the scrubby intertwined process, arguments for why specific methods have been developed and the rationale behind the decisions underlying the design process. The latter can be framed as the 'design thinking', which despite the name unquestionably involves the design methodology involved [15]. Design portfolios are one thing, another one is learning portfolios. For students to develop self-regulated learning strategies, it is vital that they understand what they know and where they need to put their efforts in order to get better [16]. The portfolio methodology aims to engage students in their learning to practice increased self-sufficiency by setting their own goals and value their own goal achievement. The metaphor of a portfolio as "something to carry papers in" also illustrates the learning portfolio as a valuable collection of things (texts, images, videos etc.) that illustrates efforts and achievements. One way of using learning portfolios is the self-evaluation diary, in which students can show and tell what they have done during a day or a week, what went well and what problems or challenges they have faced. The learning portfolio should have a different focus during the education [16].
The workbook approach was developed to provide students with support to develop design thinking and link their experiences and expectations to a future, current and historic design context [17]. It can be seen as a mix between a design portfolio and a learning portfolio. The foundation of the approach is the human instinct of reflecting on experiences, which has been framed as 'learning-by-doing' [18]. Reflection provides better control of the actions, both compared with a blind trial-and-error and to a linear process of predetermined activities that takes place without any thought or consideration [9]. A workbook approach thus guides students to plan and perform their work in such ways that reflection occurs both in the event, e.g., document and describe the work performed, and after the event, e.g., reflect on what you have learned linked to particular themes or literature. There are at least three different levels of reflection initiated by the workbook approach [17]. The first one is instinctive, fast and immediate during a work situation or conversation. This involves the student trying something out, be

it a sketch or an idea. The second level involves reconsidering the first ideas linked to different aspects and new insights gained through talking to users, peers, and teachers. The next level of reflection concerns a new reconsideration. Accordingly, higher levels of reflection can occur if implemented as part of an individual's routine design thinking process, possibly leading to the reformulation of previous and formulation of completely new design theories.

2 METHOD

During 2020-22 a project was performed to evaluate lessons learnt from the implementation of workbooks in the different courses in the IDE programme and get feedback from both active students and alumni as well as the faculty that has used the workbooks. During the project, a more common understanding of the workbook was developed among teachers, both from a learning perspective and how to present the workbook approach to the students. The study included workshops with 5th year students, feedback from course evaluations, course reflections, and reflections found in the students' workbooks themselves, further described in upcoming sections.

3 WORKBOOKS AT IDE

The workbook approach at IDE is based on theories of active and self-regulated learning, design thinking, design- and learning portfolios and some principles from the CDIO framework [19], and is currently implemented in several courses, see Table 1. The IDE workbook was implemented 2016 as a pedagogical tool for self-regulated learning and formative and summative assessment, over the years, teachers have developed their own approach to the workbook assignment. A recent exploration identified at least five different styles, ranging from the more traditional design portfolio visualising results through nice imagery and layout to the master thesis report. The IDE workbooks generally consist of written text, i.e., literature reviews and methods employed, as well as sketches, photos, and renderings illustrating the process and its results. Typically, it involves sections that deal with a) *this is me*, a page that describes the student and their experiences and competencies related to the IDE competence profile [20]. The workbook is usually structured after the chosen design process, e.g., b) *learn*, c) *design*, d) *build*, and e) *launch*, all of which have theoretical, methodological, analysis and reflection subsections. The final f) *reflections and learnings* deal with learning outcomes in terms of lessons learnt and individual experiences and challenges to address in upcoming projects.

Table 1. An outline of the different courses and workbook approaches at IDE

COURSE	YEAR	STYLE	APPLICATION	FEEDBACK	ECTS
D0030A Design: process and method	1	Workbook that describes "this is me", process, results and lessons learnt in four design projects.	Individual	Midterm workbook sessions – formative feedback. Summative feedback after final hand-in.	4
D0037A Design: theory and practice	2	Workbook focusing on telling process, results, theory and lessons learnt in one design project.	Individual	Midterm workbook sessions – formative feedback. Summative feedback after final hand-in.	7.5
A0013A Product- and production design.	3	Self-evaluation	Team	Peer feedback from team members.	3.5
D0026A Graphical User Interfaces	3	Workbook, describing process and result of a UI design project.	Individual	Summative feedback after hand-in.	7.5
D7007A Form giving	4	Workbook describing the implementation of the assignments, results and lessons learnt.	Individual	Summative feedback after hand-in.	3
M7016T Creative concept development	4	Video recording telling of learning experience.	Individual	N/A	1.5
D7008A Advanced graphic design and Computer Graphics	4	Design portfolio focusing on storytelling and visualising process and results in one design project.	Individual	Formative feedback before final hand-in.	3
D7017A Interaction design	4	Workbook where the student chooses their area for reflection.	Individual	Summative feedback after hand-in.	2
D7011A Advanced prototyping	4	Storybook focusing on the evolution of a product and the rationale for the decisions.	Team	Eight feedback sessions	2
		Personal Diary, describing, process, results and reflection	Individual	N/A	1
D7017A Product visualisation	5	Design portfolio focused on product renderings, from analogue to digital.	Team	N/A	2
D7006A Advanced Product design	5	Workbook focused on the process, results from each of the four design sprints, and reflection on learnings from each phase linked to literature.	Individual	Supervision every second week, formative feedback sessions at four times during the semester.	7.5
D7014A Master thesis project IDE	5	Master thesis report describing a design project from start to finish, describing each phase, theoretical underpinnings, results and lessons learnt.	Individual	Supervision each week + two formative feedback sessions with peers and other teachers.	30

3.1 Workbooks – bachelor level

The bachelor level design courses that implement the workbook approach, of course, have different content, but a similar focus on providing students with basic knowledge and skills in design thinking methodology, design tools and techniques such as sketching, analogue and digital modelling, colour and form theory, and so forth. The more traditional workbook approach is implemented in 3 courses.

The course content in these courses is generally divided into different modules addressing a single design project that integrates some of the learning objectives. The workbook function as an opportunity for reflection-on-action on the methods and tools and the learning outcomes the result and project gave.

3.2 Workbooks – master's level

In one of the master's level courses (D7011A), students are asked to do a project diary, focusing on describing the process and the individual students' contribution to the team's work. Students should attach illustrations and pictures to illustrate the work performed. A reflection is that some students use the diary approach and are brutally honest in the project diary. In the diary students also summarise the number of hours they do in the course, which should be about 200 h. It is quite interesting to see the reported time student spends in the course 180 h is much less than the perceived amount of time 300+ h (estimation in course evaluation). In D7017A, a portfolio workbook is implemented. The focus is the evolution of the idea/concept in the different phases, from early idea sketches, concepts and final product. The students are asked to reflect on lessons learnt in writing and primarily pictures. They should argue for and motivate their design and visualisation choices, see extract in Figure 1.

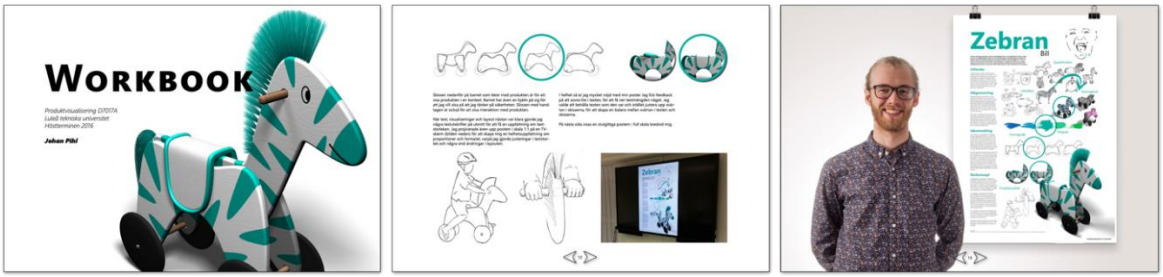

Figure 1. An extract from a D7017A workbook. Workbook: Johan Phil 2017

The more traditional workbook approach is implemented in 3 courses*: Form giving; Interaction design; Advanced Product design*. The focus is on students' describing themselves and what creative habits of mind they want to progress, the process in the different design phases, the outcomes and the results of the various phases and a final reflection, see extracts in Figure 2.

Figure 2. An extract from a D7006A Workbook demonstrating how to make decisions and perform usability evaluation. Workbook: Axel Johansson

Students express that it is easier to reflect in the final master studio course, where they have one large project for the whole semester. The students work in teams but do the workbook on an individual level.

4 RESULTS

Master students were asked to reflect on their experiences of the different workbook approaches in the courses. Now, in their fifth IDE year, they generally appreciated the approach. They were also critical to some of the workbooks. For example, if they experienced that the teachers hadn't given them the right input or tools. One teacher reflection after the workbooks have been used for the past five years in the first bachelor course is that students need to practice reflection: students' accounts of the projects tend

to be descriptive rather than reflective at the beginning of the education. A summary of the student's account of the different workbook approaches can be seen in Table 2.

Table 2. An outline of students' reflections on different workbook approaches

COURSE	YEAR	STUDENTS' REFLECTIONS (Authors' translation)
D0030A Design: process and method	1	*"It was so difficult to reflect the first time in the first course. Now, after five years, I have so much to reflect upon."* *"In the first-course year one, it was more about the "how's" rather than the "why's".*
D0037A Design: theory and practice	2	*"In the second workbook, we lacked the theory to describe form, and we neither had the language nor the tools to evaluate and describe it. What was the point of that? It just made me frustrated. The teachers must plan better for this, give us the right tools if they want us to reflect properly".* *"[It was difficult to reflect on a more general level as there were many smaller tasks that were not interconnected"*
D0026A Graphic User Interfaces	3	*"In some of the courses, there is not enough time for reflection, and the assignments are too short. You need time to reflect."*
D7007A Form giving	4	*"When you simply present the end-results, it feels like the whole learning experience is missing. You only show that you can use the tools and the software, not that you actually know something about design."*
M7016T Creative concept development	4	*"Video recordings are good if you're good at talking and can brag about yourself; otherwise, you have to write a script and then what's the point of making a video recording?"*
D7017A Interaction design	4	*"In some of the courses, we can choose what to reflect upon. Then you cherry-pick some parts that you know you are strong at, not the things you actually should improve."*
D7011A Advanced prototyping	4	*"It was really a challenge for us. Let me say that we were more at odds than ever before. Stupid to do a project like this with a best friend. So far, it has been a test of friendship."* *"I really liked to use the personal diary that focused on the reflection [not the visual presentation], easy to continuously add content after each day, then the workbook focused on the presentation of the team effort"*
D7017A Product visualisation	5	*"I appreciated doing an individual portfolio-based workbook."*
D7006A Advanced Product design	5	*"It is totally impossible to describe a joint team effort in a workbook. Usually, you divide the assignment and then you don't know all the things the others have done and learnt. You can only describe your own learning process."* *"It was really valuable to describe a whole design project from start to finish, to be able to see all of the things that were done."*
D7014A Master thesis project IDE	5	*"Now, in my master thesis project, I have returned to all of my previous workbooks. I re-discovered methods, and I saw my own progression. It gave me so much; it was a real boost!"*

All-in-all, now in their fifth and final years, they were quite passionate about the workbook approach and had a lot of ideas of how to improve it even more. Some of them had developed self-regulated strategies along the way. For example, having a physical notebook and writing down what you have done every day makes it easier to write the workbook later on. They all claimed to go back to their older workbooks and get inspiration, some more regularly than others. The workbook approach was something these students appreciated, as some of them stated that they now see it as a very good way of describing and reflecting on the work they had done. A preliminary framework for the workbook approach can be seen in Table 3.

Table 3. A preliminary framework for the IDE workbook approach

Year	Objectives	Workbook content
1-2	Developing motivation for learning, positive self-image, developing emotional competence in caring for users, communication and collaboration skills, basic design knowledge and good working habits	Self-reflection, sketches, renderings, photos, short texts with a different focus relating to course content. Creative habits of mind. Reflections after each section. Workbook dialogues with formative feedback sessions.
2-3	Consolidating and deepening knowledge in design subjects, implementing tools for learning and reflective thinking, group maturity and collaborative learning, and deepening the communicative skills and abilities to present and represent oneself and one's project.	Deepened self-reflection, sketches, images, photos, and reflective texts relating to course content, collaboration and project methods and results. Reflection-on-actions in projects and teams. Lessons learnt. Workbook dialogues with formative feedback sessions.
4-5	Deepening the knowledge in the different design subject areas' uniqueness and structure, increasing profiles or specialisations based on students' interests, and involving more independent experimentation and challenge-based learning experiences.	Self-profile, sketches, images, photos, models, and descriptions about projects/assignments. Reflection-on-action in the whole course. Workbook dialogues with formative feedback sessions.

5 DISCUSSION

One learning experience of the current project is a need for a more overarching structure and progression in the different IDE workbook approaches. A framework could, for this reason, be to have workbooks focusing on some skill development and reflection in the first years and gradually increase the reflection. All-in-all, the student's gratification shows that something in the workbook approach is worthwhile. It seems to take them a while to understand the approach, but over the years, they develop self-regulated learning strategies as a result. Teachers can guide the learning process and support students in descriptive writing, descriptive reflection, dialogic reflection, and critical reflection [10]. The first level, descriptive, is not reflective, as it just involves a report of a project, situation, or other events. The second, descriptive, is an effort at providing reasons, for example, based on personal judgements or linked to

course literature – this is what students employ in the bachelor-years workbooks. The third level of dialogic concerns exploring reasons for what has happened. The fourth level should consider a broader ethical, historical, social, cultural, technological, and sustainable context. The teacher experience from IDE is that the two first levels are more easily mastered and utilised compared to the two more challenging forms of dialogic and critical. The latter requires knowledge and an experiential base that takes some time to develop but is at IDE seen as vital for future design engineers.

6 CONCLUSION

Conclusions of the current workbook approach project are first that there is a need for an overarching framework of the workbooks to support both teachers and students in understanding the task and how it can be utilised. Secondly, the workbook approach supports self-regulated learning strategies and is, therefore, an active learning tool. Thirdly, the workbook's guided reflection is a valuable tool for reaching higher levels of learning in design.

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