Learning Together

Enhancement of Social Interaction in Physical Learning Environments

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1. Introduction

The education landscape is slowly starting to change as the world is rapidly changing due to the high speed of technological advances in all aspects of life. Some have started reimagining what education can look like in the future. The rise of e-learning has taken center stage in this reimagination, especially accelerated by the Covid-19 pandemic. Suddenly, education was forced to change and move (partly) online. As many have experienced by now, learning solely behind a screen at home neglects large aspects of the promise of education to prepare you for the future. While the advancement of e-learning raises the accessibility of courses from the best educators from anywhere in the world, the quality of the learning experience is not as good as face-to-face. Practical skills, such as engineering skills obtained through hands-on activities are difficult to obtain when taught over a distance, and the entire social aspect of learning is reduced to its online form. This removes us even further from genuine human connection. The (e-)learning experience is reduced to a limited form for social aspects such as learning from peers, learning how to communicate, and learning how to collaborate on common projects.

In this transitional phase of reimagining the future of education, 100ideas believes in the combination of virtual and physical learning experiences. They position themselves to increase the quality of education in physical face-to-face settings. Their vision of a better learning experience includes the strengthening of connection among peers and their connection to local learning environments. In these communities, learners themselves are a wealthy source of knowledge who contribute to the quality of the education experience for everyone else. However, merely creating a dedicated space for learning where individuals are put together, does not improve the learning experience. More can and should be done. New opportunities arise in attempting to improve the face-to-face learning experience.

The internship at 100ideas had two concrete objectives:

1. Create a concept that improves the learning experience for learners in physical learning environments
2. Speculate about the potential of the concept in terms of the further development of the company's Learning Analytics in a physical environment

In this paper, we present the Virtual Companion Space (**VCS**), an avatar-based online platform where people interact and find each other, based on the project people work on, where each displayed avatar is a real person presently located in a Physical Learning Environment (**PLE**) - a makerspace-like environment, where learners go to for studying or (group) project work, where optionally the space have equipment typically found in makerspaces (e.g. laser cutter, 3d printers). In this paper we zoom in on the Design Lab at University of Twente as an example of a PLE. The

VCS design concept is created through a design process and backed by collected qualitative data. Chapter 2 walks through the conducted design process, and chapter 3 presents the qualitative findings during this process. Chapter 4 provides an elaborate account of the VCS concept and how its components are connected. In chapter 5, we analyze the VCS using a data-centered lens to see its potential for the further development of the company's Learning Analytics in PLEs. This follows up with a discussion in Chapter 6 on how the VCS can contribute to 100ideas' mission to improve face-to-face education.

2. Related work

Education is slowly changing as technological advancements influence all aspects of life. Together with the Covid-19 pandemic, students and learners all over the world had to adapt to new ways of learning, where e-learning took center stage. This sudden change has accelerated the evolution of the educational landscape. Among all uncertainties currently in education, one certainty is that it will not be a return to normal (Neuwirth et al., 2020). In this chapter, we take a closer look at developments in research in education and new technology, especially from the field of Computer Supported Collaborative Learning (CSCL), aiding us in widening our perspective in what ways the educational landscape might change.

2.1 E-learning

E-learning has been a necessary technology to ensure the continuation of education when schools were forced to go online. E-learning entails a plethora of applications, processes, and learning methods, and therefore it is difficult to find an accepted definition. In this report we refer to e-learning as a medium for providing online learning through courses. Online learning brings with it a tremendous advancement in the accessibility of education. However, social processes that are situated in more traditional means of education might be too difficult to recreate online. Dumford (2018) has explored the advantages and disadvantages for engagement of online learning in higher education. They found that learners who had a greater amount of online courses had a higher degree of engagement in quantitative reasoning, while being less engaged in discussions with diverse others, student-faculty interactions, and collaborative learning, when compared to traditional face-to-face learning environments. Natural emerging social interaction that influences one's engagement was replaced by interaction made available through online means. On a similar note, Arkor and Abaidoo (2015) showed that e-learning may have a negative effect on learner's communication and socialisation skills. They additionally argued that e-learning is even less appropriate for fields where developing certain practical skills are required, such as in medical science and engineering.

Another field of research that focuses on technology in education is Computer Supported Collaborative Learning (CSCL), a "theory- and research-based pedagogical vision of what collaborative learning could be like, thanks to innovative computational support and new ways of

thinking about learning" (Stahl & Hakkarainen, 2021). Computer support for learning does not merely encompass learning online. Since e-learning has the inherent absence of face-to-face interaction and reduction of engagement in collaborative learning, the CSCL field may provide an important lens for the future of collaborative learning in education, and show ways technology can enable improvements.

Collaborative learning involves a "mutual engagement of participants in a coordinated effort to solve the problem together" (Roschelle and Teasley, 1995). Engagement increases when collaborative learning is situated in ill-structured, complex tasks in real world settings, but are all depending on the key element of social interaction (Kreijns et al., 2003). Two pitfalls were identified regarding social interaction in online CSCL environments, namely "taking for granted that participants will socially interact simply because the environment makes it possible, and neglecting the social (psychological) dimension of the desired social interaction" (Kreijns et al., 2003, p335). An online forum for the entire class is a simple example of a CSCL environment. In face-to-face learning environments, social interaction is "natural" to achieve, or is already established. It is common to think that this same pattern will be reproduced in distributed learning groups. When taking social interaction for granted, one thinks that creating features to enable social interaction will also cause social interaction to happen (Kreijns et al., 2003). CSCL environments often limit actions to the task context (action only related to the collaborative execution of the learning task) and the dimension of education (social interaction is only in service for educational purposes). This results in the neglect of the social (psychological) dimension of the desired social interaction. Forgetting this dimension of social interaction in the creation of CSCL environments leads to undesired results in collaborative learning (Kreijns et al, 2003).

2.2 Role of representations in collaborative learning

Ainsworth (2021) elaborates that the CSCL field offers many options for enabling collaborative learning, all of which the learning is representational, and suggests four key functional roles that representation plays in CSCL:

1. "Interpreting existing shared representations to guide collaboration and create shared knowledge

2. Jointly constructing representations to negotiate and express new understandings

3. Making representational choices to portray oneself or other human and artificial agents in the collaboration

4. Using representations to express and analyse collaborative activities and their outcomes" (Ainsworth, 2021, p355)

Learners in CSCL are usually tasked to interpret computational representations, with the intention to support their learning (Ainsworth & Chounta, 2021). This can range from non-interactive representations (i.e., text, video) that illustrate an expert view of a domain, to interactive representations (i.e., tables, graphs, and tangible artifacts). Within this interpretation activity, one

hones in on communicating knowledge, with the expectation of learners to advance their understanding closer towards the expert other (Suthers, 2014). Another common feature of the use of sharing existing representations is the use of the representations for negotiating shared meaning (Ainsworth & Chounta 2021).

Another way to use representations is by joint construction. Learners are tasked to jointly construct a new representation with their peers to express and negotiate new understandings. This way of using representations holds all the benefits in the previously mentioned use. The task of constructing the representation causes externalization of someone's knowledge or elicit knowledge from someone else (Fischer and Mandl, 2005). In the act of constructing the shared representation, learners' knowledge transforms from tacit to explicit knowledge (Ainsworth & Chounta, 2021). Commonly, the joint construction of a representation is a consequence of working towards a common goal, where learners are exposed to new ideas and knowledge from peers. They have to coordinate and establish a common plan of action, while managing the common resources to work constructively and efficiently together (Meier et al., 2007).

Representations can also be used to represent people digitally. These collaborators may intentionally remove clues to anonymize one's identity. Apart from negative uses resulting from being anonymous, like engaging in "flaming, or propensity towards anti-social behavior" (Christopherson, 2007), positive aspects are also studied. Anonymity can encourage people to participate with a decrease in fear of judgement and ideas being evaluated with a more critical eye, resulting in possible improved group decision making (Nunamaker Jr et al., 1996). This is due to not being afraid of retribution from peers or from those who are more knowledgeable. Ainsworth et al. (2011) made an attempt to hone onto the possible benefits of anonymity in educational settings and situations, and asked students anonymous to each other to participate in a debate about controversial issues. Affording anonymity in this way, teenage students showed higher engagement in the debate and were more likely to change their positions regarding the topics. It was speculated that the anonymity decreased the worry regarding consequences to their social relationships when they express unpopular views.

Lastly, the representations themselves can be used as the tangible outcome of (collaborative) learning activities. These representations can be used to analyze learning outcomes and analyze how peers have collaborated together (Hoppe 2009). These representations have the ability to guide learners towards more reflection and self-regulation (Wise et al., 2021).

2.3 Trialogical learning

"The recent emergence of digital fabrication technology and educational maker spaces expand the scope of CSCL epistemologically, theoretically, and methodologically, to centrally involve the role of materially embodied artefacts in collaboration" (Stahl & Hakkarainen, 2021). These created artefacts inherit the functional roles of representations. Parallel to this emergence, a novel framework is gaining traction in the CSCL field called Trialogical Learning, referring to forms of collaborative learning where individuals together systematically develop shared, tangible "objects" (i.e., material artefacts, written or visualised practices and ideas) (Paavola & Hakkarainen, 2021). It

does not merely focus on processes of the acquisition of knowledge by individuals ("monological" approach), nor processes of social interaction participation ("dialogical" approach), but on gaining a new understanding of those processes where collaboratively objects of activity are developed (e.g., with writing, prototyping, visualization, or other means) (Paavola & Hakkarainen, 2021). These objects point to the investigative nature of projects where one pursues not completely understood objects of research and development, right at the edge of understanding that provides inquiring guidance, becoming persistently and increasingly complex when studied (Paavola & Hakkarianen, 2021). This type of object-oriented collaboration is a nonlinear process where the created artefacts guide the progress of inquiry unpredictably, consequently affecting the trajectories of future collaborative activities. Within the context of education, it is different to perform learning assignments as "schoolwork", than to orient the learning activity towards solving vital problems in the community, societal contribution, and developing what is useful to others (Paavola & Hakkarianen, 2021).

To support the trialogical approach and practices, a set of design principles (DPs) were developed (Hakkarian & Paavola, 2009), that have a dual nature: (1) pointing out characteristics of "trialogical" and (2) providing guidelines for stimulating trialogical features in a learning setting. This set of DPs are:

- "DP1: Organizing activities around advancing shared objects.
- DP2: Supporting the integration of personal and collective agency and work (through developing shared objects).
- DP3: Fostering long-term processes of knowledge advancement with shared objects, whether artifacts or practices.
- DP4: Emphasizing development and creativity in shared objects through transformations and reflection.
- DP5: Promoting the cross-fertilization of various knowledge practices and artifacts across communities and institutions.
- DP6: Providing flexible tools for developing artifacts and practices." (Hakkarian & Paavola, 2009, p9)

The trialogical framework had an important starting point in educational institutions. Features of trialogical learning have been promoted in many pedagogical models, such as project-based learning, learning by design, problem-based learning, and learning by making (Paavola & Hakkarianen, 2021). Ilomäki et al. (2017) have studied the ways teachers can redesign courses using trialogical design principles, and elaborate the need for structural changes at the school level, organized time for planning collaboratively among teachers, reflecting and sharing of tried practices, to gradually adopt and implement trialogical design principles. One such school level structural change is happening currently, where fabrication technology enables practices of maker cultures in schools where objects can be created with unforeseen complexity and intellectual challenge, allowing new ways for self-expression and fostering competencies like creativity and inventiveness (Blikstein, 2014).

2.4 Metacognition in collaborative learning

With the trialogical framework set in place, learners form teams to solve real problems together, collaboratively learning whatever comes in their paths towards advancing the common goal. In what other ways can collaborative learning be further computer supported? Effective collaboration is more vast than simply completing goals or working in groups, and cannot just be enabled by providing a dedicated environment full of digital fabrication tools. Simultaneously, simply bringing a group of learners together does not guarantee proper teamwork and learning, on both the individual and group level. Transactive activities have a central role in collaborative learning (Kirschner et al., 2018). These activities, whether synchronous or asynchronous, facilitate groups to acquire knowledge about who their group members are, how the common task can be dealt with, the willingness and accuracy of the group for carrying out the task, and how tasks should be coordinated to advance and accomplish the task. Kruger and Tomascello (1986), proposed the distinction of three types of transactive activities: 1) transactive statements (i.e., critique, or extension of an idea), (2) transactive questions (i.e., clarification or elaboration of ideas), and (3) transactive responses (i.e., justifications of proposals or ideas). These transactions can be oriented towards others and to oneself. Järvelä et al. (2021) claim that regulation and metacognitive monitoring can help reduce the cost of these transactive activities in collaboration, contributing to the success of CSCL. Learners are engaged in metacognitive monitoring during collaboration, regarding their cognition ("Do I understand?"), emotions and motivations ("Does the way I feel or think cause disturbance in my learning progress?"), behavior ("Do I have all that I need to perform the task?"), and collaborative coordination ("Are we progressing with the task?").

Metacognition refers to the conscious awareness of cognitive processes (Flavell, 1979). Self-regulation refers to "..the ways that learners systematically activate, sustain, and regulate their cognitions, motivations, behaviors, and affects toward attaining their learning goals" (Järvelä et al., 2021). Viewing from the self-regulated learning (SRL) lens, metacognition is considered a source for regulation, motivation, emotion, cognition, and behavior. Metacognition through SRL is focused on metacognitive monitoring, which is zooming in on the student's qualities of thinking and thought. Metacognitive monitoring, which is inherently an internal and individual mental process, can cause co-regulated and socially shared regulation of learning, when these processes are externalized during collaborative learning (Järvelä et al., 2021). Co-regulated learning happens when individuals' regulation activities are supported, shaped, and constrained by other group members, while socially shared regulation happens when groups' regulatory activity extends from the "I" to the "we" level, regulating collective activity in agreement (e.g., by co-constructing shared goals, standards, and task perception) (Järvelä & Hadwin, 2013). Socially shared regulated learning (SSRL) can only be enabled when co-regulation and joint task understanding is established, which the following three design principles supports (Järvelä et al., 2021):

1. "increasing learners' awareness of their own and others' learning processes,
2. supporting the externalization of students' and others' learning processes in a social plane and helping in sharing and interaction, and
3. prompting the acquisition and activation of regulatory processes." (Järvelä et al., 2021, p288)

This support makes it possible for individual learners to increase the awareness of one's own and others' learning processes, enhancing metacognitive awareness (Järvelä et al., 2021).

2.5 Group awareness and learning

Additional tools for supporting the process of collaboration can be found in CSCL work on group awareness (Buder et al., 2021), which is the state of being aware of cognitive and social attributes of members of a group, and awareness of created products from group members. Group awareness can point to different types of groups, ranging from dyad groups to whole communities of thousands. Members of a group who receive visual feedback regarding the group and their members, can use this information to improve regulating interaction within the group (Buder et al., 2021).

In the early stages of research in group awareness tools within CSCL, the focus was on information that is visible when learners are in a face-to-face setting. This changed by going beyond merely imitating face-to-face settings for collaboration where groups are physically distributed, and redirected to searching the added value computer support could provide in distributed and face-to-face settings alike (Buder, 2007), by providing data that is not easily observable (e.g., knowledge of members of a group). Buder et al. (2021) provide a classification of group awareness tools within CSCL research, categorized within two dimensions (see Table 1).

Table 1 Classification of group awareness tools, organized by type of information (in rows) and functional levels (in columns) (Buder et al., 2021)

Level	1	2	3	4	5
	Framing	Displaying	Feedback	Problematizing	Scripting
Cognitive group awareness tools	Preparing knowledge exchange	Showing partner knowledge	Enabling comparisons of knowledge	Indicating cognitive conflicts	Structuring knowledge exchange
Social group awareness tools	Preparing for group interaction	Showing social attributes	Enabling comparisons of productivity	Indicating conflicting issues	Structuring social reflection

The first dimension (cognitive or social group awareness tools) distinguishes between the type of data that is provided between cognitive group awareness tools and social group awareness tools. The cognitive group awareness tools focus on cognition and metacognition (e.g., know who holds what knowledge, or know peers' attitudes and opinions) while social group awareness tools direct their attention towards behavioural, motivational, and emotional aspects. The second dimension categorises five psychological functions that are performed during collaboration (framing, displaying, feedback, problematizing, and scripting), that the specific group awareness tool affords. Take note that tools that support a higher level function (e.g., feedback), also fulfil the lower level functions (e.g., framing and displaying).

Group awareness tools classified in the third functional level provide the psychological function of feedback about cognitive and social behaviour. This enables comparison of these behaviours,

leading to adjustments in regulatory behaviour, whether comparisons are made between oneself and others, between different people, or between "products" that oneself or someone else has created. Social comparisons can help validate someone's performance or opinions with regard to a group and can start a change in behavior. For example, Buder & Bodemer (2008) created a cognitive group awareness tool where learners were required to rate written discussion posts from members of their group on two dimensions (novelty and agreement). This rating is visualized on each post. Learners therefore receive feedback on the comparison between different posts. Empirically, the study showed that written posts made by learners who hold a minority view became more salient, leading to better group decisions. Likewise, the participant meter tool (Janssen et al., 2007) is a social group awareness tool that displays average length and number of created discussion posts by an individual. This data becomes the means to compare participation behavior. The study found that this tool increased participation, but had no direct impact on group products.

Järvelä and Hadwin (2013) elaborate that feedback can lead to self-regulation. Some group awareness tools take a step beyond by providing data that leads to socially shared regulation. Particularly, the tools problematize (fourth functional level) issues about collaboration (i.e., displaying differences between group members that are meaningful, or notifying group members about problems in relational aspects). For example, the GKA tool (Dehler et al., 2011) is a cognitive group awareness tool that visualizes the difference in understanding of learning passages. These differences are displayed to the learners, functioning as a useful cue to the dyad members (e.g., A does not understand the passage while B does, naturally B is prompted to explain the passage to A), and resulted in guiding the decisions of learners about what to ask and what to explain. A tool that supports the problematizing function in social group awareness tools is the S-REG environment (Järvelä et al., 2016), where learners self-rate on multiple emotional, cognitive, and motivational states are aggregated on the level of the group and displayed in three colors (green, yellow, red). The lowest individual rating determines the group-level information. For example, when two group members rate being very motivated (green light), and one member rates being moderately motivated (yellow light), the group receives a yellow light for motivation. The use of S-REG served as a basis for discussion regarding problems that emerged in the groups. Group awareness tools focusing on the problematizing function providing meaningful data to a group, where it is likely that corrective processes to resolve issues are started among learners, enables socially shared regulation (Buder et al., 2021).

2.6 Learning analytics in collaborative learning

Most state of the art group awareness tools relied on explicit ratings or actions that learners needed to provide (Buder et al., 2021). A trend is emerging within the CSCL field to partially automate the gathering of group awareness data. Recent developments in learning analytics could play an important role in the future in collecting collaborative process data in an unobtrusive manner (Buder et al., 2021), opening up possibilities for new research and development of novel mediation tools to stimulate collaborative learning in situ. Likewise, metacognitive monitoring is an inherent internal process where current analytical methods rely on the learners' externalization of metacognition (i.e., by speaking about it or writing it down), hence, only partly capturing

metacognition. The understanding of collaboration processes relies on research focused on insufficient measures about collaboration (e.g., chat-logs, self reports, video, with which the discourse can be analyzed) (Järvelä et al., 2021). Recent advancements in computational technology open up a new set of data for understanding collaborative processes through process-oriented instruments, physiological indicators, and real-time multimodal measures (Järvelä et al., 2019). While most learning analytics research and tools have focused primarily on data collection from online learning environments, multimodal learning analytics has the potential to provide new insights into learning, especially in tasks where learners have space to create personalized artifacts (Blikstein, 2013).

With these new developments integrating with the field of CSCL, what new insights can be discovered? The examination of collaborative learning processes through (multimodal) learning analytics means that the field gains a quantitative perspective and an ability to know "where to look" for detailed qualitative examination (Wise et al., 2021). However, apart from using learning analytics as a research tool, another aim is to research and develop learning analytics as a mediational tool for improving collaborative learning. Wise et al. (2021) elaborates that "such Collaborative Learning Analytics (CLA) create a feedback loop for generating information that can trigger computer-initiated adaptations to the conditions of collaboration or be provided to students and educators to provoke reflection, and potentially, changes that improve collaborative learning". (Wise et al., 2021, p431).

2.7 Lessons learned for design

The majority of education technology companies have primarily focused on online learning, due to the available online data, established learning analytics practices with online data, and the potential to scale dramatically due to its worldwide reach. However, e-learning cannot replace or recreate learning environments in physical settings. Simply creating features to make it possible for learners to interact with one another in a distributed setting, does not mean that social interaction will happen. We position ourselves to avoid recreating social interaction online as a replacement, but rather take advantage of technology to promote physical social interaction between learners.

Representations fulfil many roles in collaborative learning (a learning situation where the mutual engagement of learners is coordinated to solve a common problem or challenge). Representations can be seen as any artifact that functions as a medium for collaborative learning. Learners (1) interpret representations to communicate knowledge to get to the level of understanding of the more expert other, (2) create joint constructions where tacit knowledge is transformed to explicit knowledge and communicated, (3) identify themselves with a representation to potentially decrease fear of judgement, and (4) analyze collaborative outcomes to guide reflection and self-regulation. We take note that we should aim to design the possibility for representations to be more discoverable and shareable across learners in a PLE. These representations should fit within the core activities of PLEs, namely the creation of artifacts in projects. This design lesson is in line with the first design principle to promote trialogical learning, proposed by Hakkarianen and Paavola (2009),

namely to organize activities for advancing shared objects. Likewise, with the assumption that learners in PLEs come from different fields, increasing their likelihood of sharing artifacts and representations is in line with the fifth design principle (Hakkarainen & Paavola, 2009), to promote cross-fertilization of knowledge artifacts and practices across communities.

During collaboration, learners are engaged in metacognitive monitoring, such as questioning whether they understand what they are learning, or asking themselves whether a team is progressing well towards a common goal. Järvelä et al. (2021) have shown that, when metacognitive monitoring is externalized and shared to other learners, it causes co-regulated and social shared regulation of learning. We intend to design in line with their proposed design principles to support socially shared regulated learning, namely to increase the awareness of learning processes of others and themselves, and to provide new ways to support externalizations of learning processes of the learner and other learners around them, in a social manner.

Additional tools to support collaboration processes can be found in group awareness tools, where group awareness means being aware of social and cognitive attributes of members in a group, and the awareness of developed products coming from the group. Group awareness tools went through the evolution from focusing on recreating social interaction virtually for supporting group awareness, to seeking new ways to use technology to enhance collaborative learning in face-to-face and distributed settings alike (Buder et al., 2021). This was due to the possibility of providing data to learners that is (without technological support) not easily observable, in turn increasing group awareness. These tools can be categorized by their focus on cognition (e.g., who knows what, or knowing the opinions and attitudes of peers), or their focus on social attributes that pay attention to emotional, motivational, and behavioral aspects of oneself and peers. We aim to design for both cognitive and social attributes, particularly in the functions for feedback and problematizing (see table 1). Regarding the cognitive attributes of these functions, learners are able to compare knowledge and indicate cognitive conflicts (i.e., I do not understand how to move forward). Regarding social attributes of these functions, learners are enabled to compare productivity and indicate issues (i.e., noticing that the motivation level of a group is low).

3. Design Process

In this section, we outline the design approach that formed the guide of the performed design iterations. The DOIT design process (Mackay, 2020) was used as a guide to determine when and which design activities should be performed during the process. This is followed by the elaboration of pivotal design activities, and data analysis with the described participants.

3.1 Design Of Interaction Things (DOIT)

The DOIT process (Mackay, 2020) is split into four phases, namely (1) discovery - who is the user, (2) invention - what is possible, (3) design - what should it be, and (4) evaluation - does it work (see figure 1). Each of these phases consists of activities that collect data, explore the data, and produce some output that encompasses all that has been learned and processed within a phase. For example, in the invention phase, one might start with brainstorming to collect possibilities, explore the ideas by categorizing them, and use this to produce a design concept, which is used subsequently for the design phase.

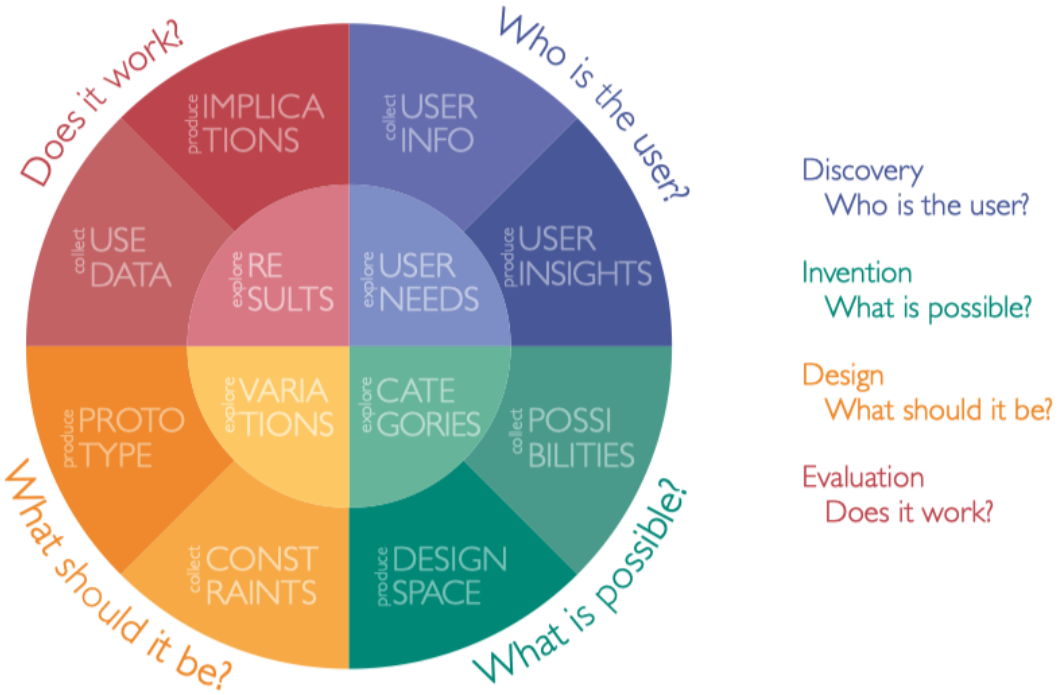


Figure 1: Design Of Interactive Things (DOIT) process

Although it seems that a designer should chronologically follow the design phases in a clockwise manner, it is up to them to decide which activities follow which. Insights during this process can happen at any moment and one is free to decide what design activity is most appropriate at the moment. However, each activity has the unifying characteristic that it always results in producing something, whether it is a summary of collected data, feedback from your peers, ideas or prototypes (Mackay, 2020). An elaboration of all the available design activities in this process is out of scope for this thesis. However, more information can be found in Mackay's work (Mackay, 2020). A couple of pivotal design activities are explained in further detail.

3.2 Story Interviews

The collection of the initial pool of user information (in the discovery phase) was obtained through story interviews (Mackay, 2020) and were conducted online, through a video conferencing software. Participants share stories about when they (1) learned something from someone else, (2) taught something to someone, and (3) learned something memorable. The story interview technique is based on the critical incident technique (Flanagan, 1954), to gain access to behavioral facts that are significant and specific. Stories in this context are a recall of an event (or incident) which has happened in someone's past. The following three questions are asked to trigger such stories:

1. Can you think of a time in the past when you tried to learn something from someone else?
2. Can you think of a time in the past when you tried to teach something to someone?
3. Can you think of a time in the past when you tried to learn something memorable?

Although these questions probe for stories, it does not necessarily mean that a specific story is shared, but rather an abstract form of multiple stories. Interviewees often drift off from the specific story and start sharing what **usually** happens instead of what happened in a specific instance (i.e., "usually I would learn by doing"). When this happens, it is key to steer the interviewee back to their story line (i.e., "Interesting, can you give an example when you did this?"). Apart from keeping the interviewee from drifting off a story, the interviewer needs to pay attention to probe for details, context, and interactions. This is done by asking follow-up questions such as:

- What did you do first?
- What happened next?
- Then what happened?
- Where were you when this happened?

The collected stories provided the stimuli and context that was needed to start ideating and designing a prototype.

3.3 Creative Platform

To find what is possible, a creative process called "the creative platform" was conducted (Byrge & Hansen, 2014. During this process, it is easier to apply knowledge in an unrestricted manner, where links between knowledge and ideas can more easily be established, and where one can increase creativity while training their creative ability (Byrge & Hansen, 2014). I had the privilege to be trained to facilitate the creative platform by the authors over a period of five months. Elaboration of this process is out of scope, but a full account of the creative platform and how one

can increase creativity can be found in Byrge and Hansen's work (Byrge & Hansen, 2014). The process was conducted with the company supervisor and took a total of 2 hours, where 90 ideas were produced. Although the creative platform is most effective with more participants, this was not possible due to current (covid-19) circumstances. The ideas were categorized in terms of how realistic a production version can be implemented (easy, medium, difficult). Through this process, the first version of what led to the main design artifact was conceptualized.

3.4 Prototype v1 experiment

The prototype is used to stimulate the participants' imagination of (1) how it could be used in context and in their lives, (2) whether the use of the artifact is deemed valuable, and (3) why it is deemed valuable. The main purpose of these experiments is to collect answers to these 3 points. These experiments could be seen as part of the market research of the artifact, as it taps into qualitative data of perceived value by the target group. These prototype experiments were performed completely online, through a video conferencing software.

First, the participants are introduced to the goal of the experiments, how the following prototype can be used in their lives. A few introduction questions are asked regarding their experience working in PLEs, mainly the design lab. These questions dig into how often in a week they visit the PLE, what they do at the PLE, why they go to the PLE instead of other spaces (i.e., the library), and whether they have experienced annoyances in the PLE. These questions also place the participant in the context of thinking about experiences in the PLE, as set up for the next part.

Subsequently, a link of the prototype is shared that they can open on their computer. Here we emphasize that all the avatars on screen are actual people currently located at the PLE. They are told to perform a set of tasks that can be solved by using the prototype. These tasks are as followed:

1. You want to work on a new project but do not know what project, so you decide to look for a project to join or apply for, how would you do that?
2. You want to add a project that you have recently started, how would you do that?
3. You want to meet up with someone to help them out, how can you make that happen?
4. You want to learn how to work more hands-on with electronics, how would you do that?
5. You have an idea for an event and want to create one, how would you do that?
6. You are working on a project and you want to hear how other people have done similar things to gain new perspectives. How would you do that?
7. You see that you have a message and want to see what someone asked, how would you do that?

While the participants are solving these tasks, they are free to express their opinions or explain why certain aspects are deemed valuable or not (I.e., such as saying “oh that’s nice” or “I would not use this”). It is important for the interviewer to probe for more details, especially why something is valuable or not, in what situations the prototype can add value, and whether these situations have happened to them before in the PLE. If they do remember such an instance, a story of that exact situation should be asked for, using the same technique as described in chapter 3.3 about story interviews.

After the completion of the tasks, three main follow-up questions are asked to collect answers for the main purpose of the experiment:

1. How do you see this prototype fitting into your life and activities that you do and why?
2. What were your top two aspects and bottom two aspects of the prototype and why?
3. What are things you wished were available in the prototype and why?

The last part in the experiment is to perform a brainstorm with the help of using a brainstorm visualization tool (FigJam). The goal is to build on top of each other’s ideas, by answering every idea with ”yes, and” (Byrge & Hansen, 2014). The facilitator writes down every idea in FigJam, where an arrow represents an idea that was built on top of the previous idea or a new idea triggered by the previous one.

3.5 Prototype v2 experiment

The experiment was conducted in exactly the same format as described in chapter 3.5. However, the given tasks were altered. The participants had to perform the following tasks:

1. You want to see what projects a person is working on and what he/she wants to learn, how can you do that?
2. You see that someone has a question and you want to meet him to help him out, how can you do that?
3. You are working on a project and you want to ask a question to someone who is working on a similar project, how would you do that?
4. You have a question and want to ask this to everyone in the design lab to see who can help you out, how can you do that?
5. You see that you have a message and want to see what someone asked, how would you do that?
6. You see what someone wants to learn and you want to get in contact, how can you do that?
7. You want to specify and share what it is that you want to learn, how can you do that?
8. You want to help someone who wants to learn something, how can you do that?

3.6 Data analysis

Both the story interview and prototype experiments were analyzed in the same manner. The sessions with the participant were voice recorded, with an addition of a recording of the participants' screen when interacting with the prototype. First, a complete transcription was created from the voice recordings. Each interesting part of the transcriptions were highlighted, numbered, categorized by a common characteristic, and visualized in category cards (see figure 2). Here the common characteristic is at the top of the card, while a short summary of a highlighted part in the transcription was presented, together with the corresponding number. This was to increase the ease of finding back specific and insightful parts of the data.

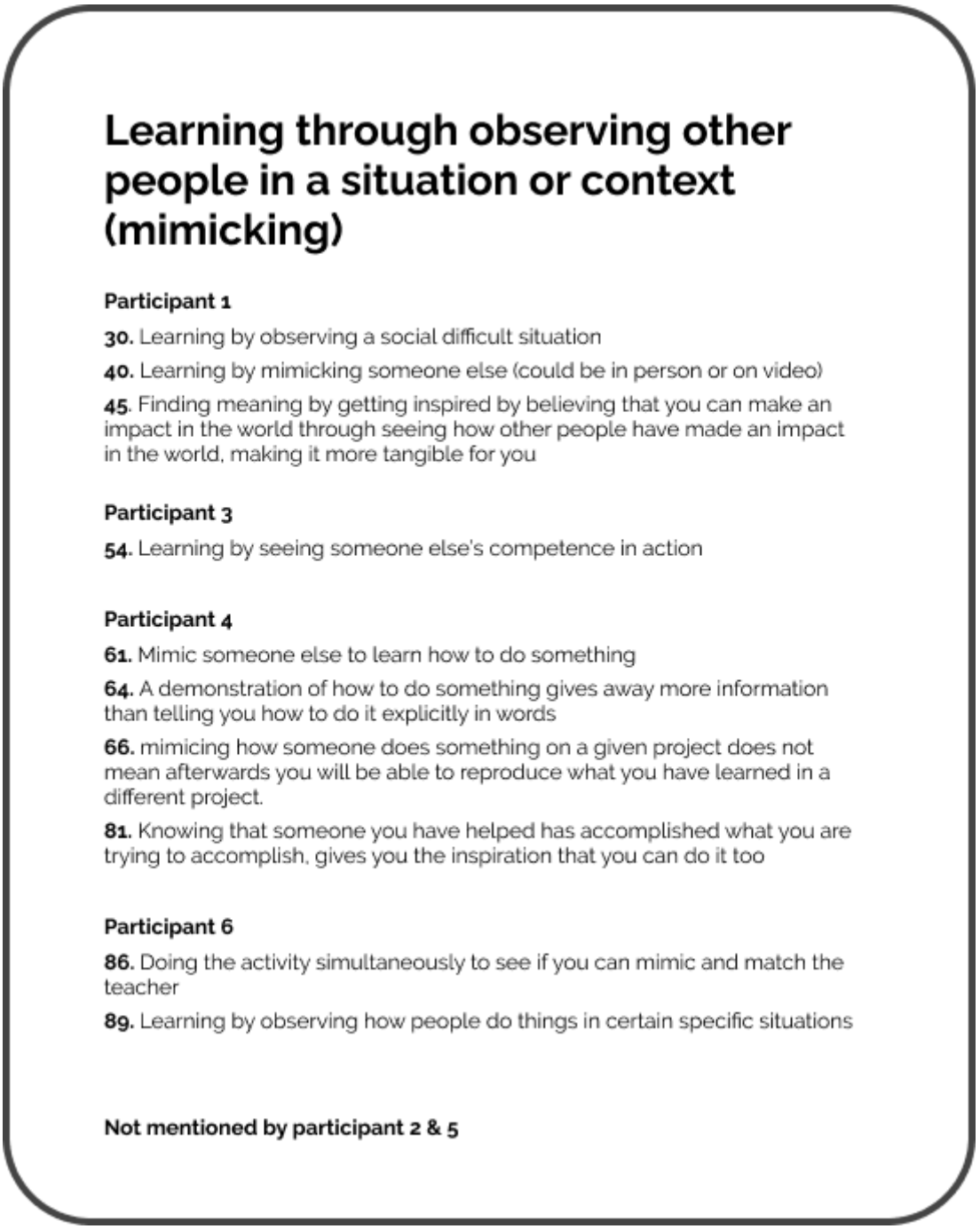


Figure 2: Category card

Annotations were made about the participants' interaction with the prototype and added as side notes in the transcriptions. In the end, the transcriptions and the category card together are used to create the next interaction of the prototype.

3.7 Participants

The participants are chosen based on whether they have had at least one working session in a PLE during their education. This is to accompany multiple perspectives ranging from individuals who work at a PLE every day, to those who have tried it and did not prefer it over other working spaces (like the library), to account for getting an understanding for these preferences.

4. Findings

In this chapter, we present a synthesis of the findings of the story interviews and prototype v1 & v2 experiments.

4.1 Findings Story Interviews

Six story interviews were conducted with a total of 4,5 hours of recorded interview material of 43 distinct stories. The participants are between 21 and 27 years old. 5 participants are studying at a technical higher education institute and 1 recently graduated. 3 participants regularly worked in the Design Lab and 3 participants preferred to work somewhere else. The story interview data formed the basis for creating the first version of the VCS.

Two recurring themes emerged from the collected data: (1) learn more practically through projects or contexts, and (2) learning from other people. We first go through these themes and afterward provide a few honorable mentions.

Learn more practically through projects or contexts
The main theme in this category is regarding learning something practically through projects or providing a context. A project or context can be seen as a vehicle for learning. One story from a participant who taught physics to high school students, observed an increase in the level of interest from the student by tying the theory to a context of the student's personal interest in cars. In this story, cars became the context for learning physics. She said that *"I told the kid to imagine that you are in a car with your parents, and you can feel the acceleration in the back. This is when you know you are increasing the velocity."*

Another participant shares a story about how working at a bowling center has helped to understand the operations management course. *"During my bachelors, I just came out of my old job at the bowling center. In my first and second semester I was learning operations management, how to structure a company and the operations planner. I could instantly see how the theory applies in the bowling center."* The mere fact that the participant had experience working at the bowling center gave them the context to apply (in his head) newly learned theoretical concepts in operations management. The participant also mentions that "*as I progressed in my bachelor's, the [learning] material got more theoretical and I had a much harder time at the end to actually envision how to apply what I learned".*

A participant was learning how to code through an online Udemy course and had an insightful approach. Instead of following the projects that were being built in the course, the participant created his own personal project as a place to apply programming concepts from the videos. They explained that *"when I just follow the tasks in the course, it does not mean that I can build my own thing afterwards. I still feel like I am at ground 0 again. It is easy to mimic things when they tell you exactly the steps in between. But when you need to mimic the outcome, with your own steps, all of a sudden you have to start from scratch."* They started to build their own project, and along the way they would identify what concepts they needed to learn. For example, they needed to build a complicated structure of a list and could skip to the video that explained the concepts of lists. They explain that *"because I skipped a few videos, I would have some gaps of knowledge about the course project. It would not matter because the person in the video uses the course project as a vehicle to explain the concept of lists. I did not need to know exactly how the course project worked, I just needed to know the context of how they were applying the concept of lists".* In this story, creating your own project shows you what concepts you need to learn to advance. Likewise, the project in the course provided the context for applying a programming concept.

Not only does working on your own project show you what you need to learn to advance, it gives you a chance to stumble upon problems, which are undetected otherwise. A participant shared that *"in a text book, it looks all quite easy and straightforward, but the moment you start applying it, you hit quite many dead ends sometimes. You encounter obstacles that you need to somehow overcome, and that is not really taught in theoretical teaching at university, how to overcome these obstacles".*

Learning from other people

Another important aspect of the story interview data was the notion of people's experiences in learning from other people. A pattern emerged regarding learning by understanding someone else's perspective and how they applied it. One participant mentions that *"[I can learn] when they share how they see it and how they apply it in their life, so that I can get inspired from what they do. Inspired in a way to understand examples of different perspectives how things can be done".* This applies more

towards non exact sciences, as in these realms there exists many ways of applying things differently, not like *"math or physics, where you can only have one way of doing certain things."* Another example was from a participant who was in a lecture where *"[the lecturer] would ask us to make a cost calculation of a start-ups case, where they would afterwards show their view of what to look out for in this calculation. I learned at that moment that I was missing lots of overhead costs."* Another participant remembers building a control scheme in Matlab Simulink for a project. Something was not working and *"I messaged one of my friends who was working on the same part in another group. I looked at their control scheme and they explained to me what specifically goes where and why. Afterwards, I tried to implement this into my own project and helped my other team mate to build the control scheme."* Lastly, a participant observed that *"I am not often in situations where I definitely know something better. In that case I would rather have a discussion [of how we view the situation differently] rather than me teaching someone something."* These stories show that there is a lot to be learned from other people's perspective on different matters.

Not only can you learn from someone else by understanding their perspective of application, but also through observing people in a given context and mimicking their behavior. One participant said that *"I learn a lot by mimicking others. I learned to play the violin quite well by solely watching and listening to what my teacher did and mimicked him. But I cannot read music sheets. So if someone asks me to play a C#, I would not know how."* Similarly, they mention that they got inspired by reading the book called Factfulness. *"The author had such an impact throughout the world, and then seeing myself in that position to see how I can make that kind of impact [was inspiring]. If you show to students how that could look like or what that could look like from somebody else, it will make it more tangible, and give you ideas and inspiration where you could perhaps create impact."* Another participant noticed that demonstrating how something is done gives away more information than explaining explicitly. In this story, a friend was telling the participant how to make oatmeal with eggs. "*I tried what they explained and sent them photos of the result, and it was all wrong. They eventually came over, demonstrated it to me, and I saw immediately what was the problem. They told me that I should add ⅓ cup of water, but his notion of ⅓ cup was not the same as mine. It turns out it needed just slightly less water than ⅓ of a cup."* This story shows that observing a demonstration of some act gives away implicit information that is oftentimes lost.

Another pattern that emerged was learning from interacting with someone with more experience. One participant had to assemble many electronic parts together and said *"whenever I could not figure out something, I would send [the expert] a message and he would come to see how he can help me out with a problem. I needed help with troubleshooting so we would troubleshoot together and eventually get it right."* The participant mentions that *"because of their expertise, they can explain and show me straight away what electronics can do which function. They gave me the right level of guidance to help me understand it better."* Similarly, another participant gave a decent pitch with quality content, but was lacking in another aspect in pitching skills. The pitching teacher gave

personalized feedback that *"you want to also connect with the audience on an emotional level. You want to know who the audience is and carry them through your presentation. It is not only about good content. They have to recognize themselves in the content to care about it."* The participant said that *"I never really realized that my content should also click to the person who I am talking to. Now I have incorporated it in my following pitches and also I realized that you can focus way more on who the people around you are."* This participant learned something valuable because the teacher personally gave them high quality feedback and showed them how they could incorporate it.

Honourable Mentions

Because of the vastness of the collected data, lots of other patterns emerged that did not occur as often as the two mentioned above. Nevertheless, they are like hidden gems that need to be mentioned. One such gem is regarding learning methodology. The participant has the opinion that this is poorly done in most higher education institutions (at least in their experience). They remember that *"during risk management class, the teacher asked us to brainstorm about what kind of risks we can think of. One student would name one risk and another student a second risk. It was a big mess. In a consulting setting, there is no value in naming a random list of risks. So during such a brainstorm, it would have helped to teach a method of a structured way of discovering risks, something important in the workplace. But this was never taught to me during my bachelors."* They add that *"what I complain about a lot when it comes to my education experience, is that we learn a lot of content, but rarely methodology. If you know the methodology, you can teach the content to yourself."* In a similar fashion, another participant was teaching someone their method to problem solve something in Excel. They were asked to explain a concept and forgot how to do it. So they *"showed them how to find the solution on their own, which is how I do it. I told them I forgot how to do this, went to google and searched for excel formula parsing, and then you can go to the reference website and there they will explain it."* They ended up explaining how they do their own problem solving in Excel.

Another hidden gem is regarding learning about yourself. One participant emphasizes the importance that *"I think a great thing that everybody should learn is learning about yourself and learning about your goals in life and your personality. Your specific needs and specific goals in life, it helps a lot to know that. Because many university students, they don't know what they want to do in their life, and there is no purpose or direction at all."* Another participant shared that *"some courses I think that I just have to learn to pass because I know I will never use it again especially in my job later in life. But some courses are interesting and I think it's cool and I want to actually apply it in real life. If it is something relevant [for my future] I will enjoy it more, generally, because I know I want to use this later in life and I might as well try to learn it and then I involve myself more in it"*. For this participant, because they had set an aim, they knew for themselves which courses they wanted to pay extra attention to, and which ones they just had to pass.

4.2 Findings Experiment Prototype 1

Four Experiment interviews were collected with a total of 4 hours of recorded interview material. The participants are between 21 and 27 years old. All participants are studying or have studied at a technical higher education institute. 2 participants prefer working in places like Design Lab, while the 2 others prefer working somewhere less distracting. This chapter elaborates on the two most valued aspects of VCS including the reasons why. These value propositions of the artifact have eventually led to discovering a potential underserved need for learners in PLEs. What this underserved need is will be discussed at the end of this subchapter. The collected data from this experiment formed the basis for the second version of the VCS.

Increase in overview of what is happening in the learning space

3 out of 4 participants see value in the extra overview about the learning space. Especially about the extra information that is available about their peers. One participant mentions that *"it's like having a bird's eye view where you can very quickly see what is happening in the learning space regarding projects and events."* Another participant shares that *"I would be constantly curious looking at what are the active projects, what projects did people work on, and how do they link to what I am working on now."* The third participant explains that *"I can see all the active projects that are being done, I can see exactly what is going on in the learning space."* These three participants have expressed perceiving value because of access to extra information about the learning space. It is the next valuable aspect that gives the reason why these participants see value in this increase in information overview.

Ease of knowing who to interact with

All participants have expressed that this aspect is what they value most. Since learners now have access to what peers are working on, this content becomes the reason for someone to choose to initiate interaction. A participant said that *"I value that it gives me the ability to connect more easily with people who share the same interest. This builds a good bridge to target the people that you know share the same interests. You can meet them to get to know them better and see whether you share the same values to be able to work together."* This same participant said that *"when I am in the Design Lab, I would not initiate interaction, and that is why I did not meet other people there. When I was going to the Design Lab everyday, I did not have an idea what kind of projects were going on around me."* Another participant expresses a similar point that *"because I am an introvert who doesn't really like to approach people all the time, I think this really helps remove some barriers in getting in contact with other people, and spark some interesting conversations and collaborations."* They point out that *"it's all about having a reason to approach somebody. When you already know what their projects are and know what they are working on and it is related to your work or you are just interested, then now you have a reason to interact."*

The reason that the participants know who to interact with is due to the identification of potential value that can flourish from interacting. A couple mentions of this potential value are learning something, finding people to collaborate with, gaining new perspectives, finding like-minded people, and possibly getting to know new fields. A participant shares that *"I would like to have side projects and I would like to learn from the people that are in this space and the skills that they have. I can already see myself asking questions if I am stuck in something."* Another participant shares that *"I can now more easily find which people with matching interests or projects and who can help each other out with questions."* A third participant expresses that *"it makes it easy to decide and figure out who I might want to connect with. You can see everyone in this space and it gives me this community feeling that everyone is working and learning something."* They add that currently, when one sees someone working on something physical in the learning space, *"I can see what they are doing, so I*

don't know if this platform would add value there. But if they are working on something on their computer then you do not know what they are doing. In these cases this platform would add value here, you can also see what these people are working on."

Discovery of an underserved need

The participants have expressed themselves in what they find valuable about the prototype. It pointed to kinds of interactions in PLEs that seemed not to happen as often as one would like. In other words, there seems to be an underserved need in the PLEs, something of high importance and which is currently not satisfied enough. As one participant points out *"one of the reasons why Design Lab was established was to have a space that stimulates interaction between students of different fields. What [the Design Lab Team] have noticed is that people would just sit with their own group instead of interacting with others."* It seems that the organization of the Design Lab, as well as the learners working in Design Lab have the same desire. Something is stopping the learners from interacting with those they do not know. From the experiment data, I hypothesize that learners do want to connect with people with similar interests, but approaching a stranger is like a shot in the dark, you don't know if it would click before you initiate contact. Therefore, you do not try to initiate contact with a stranger in the first place. This clue of a potential underserved need became central to the next iteration of the prototype.

4.3 Findings Experiment Prototype 2

Five Experiment interviews were collected with a total of 6 hours of recorded interview material. The participants are between 21 and 27 years old. 3 participants have often worked in places like the Design Lab and 2 prefer a place with fewer distractions. All participants are studying or have studied at a technical higher education institute. Here we present common themes that emerged from the interviews. These findings were used to create the final and third version of the VCS, described in chapter 4.

Ease of finding the right person to interact with

Similar to the findings of the previous experiment for prototype 1, the ease of finding the right person to interact with stood out as the most frequently acknowledged added value among all participants. One participant draws similarities between the prototype and events organized in the Design Lab called Tosti Talks, where you get free Tostis while people sign up to talk about a topic. They say that *"These events enable students to meet spontaneously, it's like an icebreaker. People would likely not interact without ice breakers. For the tosti events, it gives a signal that someone is open to make new connections merely because of their participation."* They continue that *"with this prototype, when I meet up with someone to offer my help, this could also be like an icebreaker to get to know the person or project."* Another participant shared that when those who have a question can find the right person who could help *"you can help each other speed up in an environment where everyone is*

already busy." They continue that *"the mere fact that this environment is online, you can more easily reach out to someone. Because the hurdle to reach out is lower online than in real life, especially those who are insecure. This could lower this hurdle while giving more insight firsthand about the person."* They suggest having some kind of tags for topics so that people have a better chance of finding projects that are similar. On a different note, a participant says this prototype enables *"everyone to have this option to contact anyone in the [physical learning space] for immediate help. It's almost like no shame in it. It makes it very easy for someone with [social anxiety] to reach out for help. That is a big plus for me."* Another participant who shows more extroverted traits says that *"when I am in the physical space, I would use this to find people around. Mostly for that only, because all the communication I will just manage personally."* This indicates the potential value for finding the right person to interact with for both who lean more towards introversion as well as extroversion.

Inspiration and motivation

The prototype can potentially increase motivation and inspiration, according to three participants. One explains that *"I get a sense of community of people learning together, which is motivating to me, whether I am learning or working on a project. It gives me energy to keep doing what I am doing. That is what I like about going to the design lab in the first place, you can feel that energy, it's one of the nice things about it."* They further elaborate that *"I also see inspiration to try new things and to broaden my horizon. It's inspiring to see what people do, and it gives me a sense that I can also do that myself. It starts with seeing what people are working on [that motivates and inspires], but it's extra nice that there is a call to action to actually connect."* Along the same lines, another participant points out that *"it would give me an extra piece of motivation because I become accountable for the goals and projects that I have set for myself. People see it and could interact through that, which could lead me to working more on it because people will approach me about it."* Another participant mentions the possibility to motivate others to join your project. They say that *"if I can share the reason why I want to learn something, and link it to my project, this could get people to join your project and attract people who are interested [in a similar way]."*

Desire for extra context

Several mentions have been given regarding the potential for added value when more context can be given about a learning goal or a project. One participant who is scrolling through the Learning Hub shares interests in knowing how someone is learning something. They explain that *"what I want to gain from the learning Hub is people's experience in learning something."* They acknowledge that having the link between the learning goal and project gives them some idea of the context of how someone is learning. They elaborate that *"if I know that a project is worked on in the Design Lab, I can go there to see the project. Then I have an output to connect to their learning goal. It's learning by observing how someone has applied it that gives me a sense of how to learn it myself."*

Another participant has a similar wish to have access to more context, but regarding receiving questions. They explain that *"it should not be my role as a helper to ask for more information about a question. It should be the role of the person who is asking to provide a high quality and clear question. Otherwise, with a bad question, no one will probably respond."* They continue that *"if someone asks me a question that is linked to their project, then I can directly see what the project and question is about."* In other words, the link between a question and the project that is relevant to the question (the context), raises the quality of the question. They further wish to know where the project has been, where the project is now and where they are heading towards. This results in getting an improved context surrounding a question. This participant stresses on the importance of receiving clear questions because of the desire to respect people's time and efforts. They express annoyance if they need to put in extra effort asking for more information about a question, if the question is not entirely clear. Similarly, they explain that *"I would only like to see questions that are at least somewhat related to what I know or have done. It would bother me if I read questions the whole time that I can clearly not answer. This would make me ignore all the messages that will pop up in the virtual space."*

Desire for "proof" of skill or experience

One participant made the remark that *"saying that you have a skill does not mean that you actually possess it."* They elaborate further that *"if you can show in your project that you have done certain things, then this could function as some kind of 'certificate' for the skill, to which you can help someone else. This way, it feels more genuine, it feels that there is really an opportunity to get someone's actual skill set and interests out of their profile."* This remark gave the insight that the (finished and current) projects of someone is like a trail of experiences, to which you can point to when elaborating what skills or experiences someone has. This could increase the ability of people to find the right person to ask for assistance, more efficiently.

Other ways of using the prototype

Two participants have shared their view of the potential of such a product when incorporated in companies. For one participant who aims to do consultancy work shares that *"I could really imagine working on an organizational level in a company, where I can quickly get to people that have information that might help me."* They elaborate further that *"in many consultancy companies, where there are many people who worked on many projects before, quite some projects are pretty similar in some ways. So, if I could get a quick catch up call with somebody who had a similar project before, this is very valuable, and is often done already."*

Another participant who works at a small consultancy firm, says that *"it would be valuable if you can create such an overview of all the different initiatives taken in big corporations."* They explain that these big companies can easily lose sight of initiatives because of their enormous size. They add that *"you can create a sort of community of practices around a certain topic."* They give the example of one of their clients where lots of people are interested in 3d printing and some even have one at

home. *"You won't know these interests from people when you talk with them briefly. If they can discover each other through such common interests, ideas might come out of that."*

They also share that they could see this prototype work in their personal setting where *"I am able to create my own lab, can ask friends or others to join, in which you get positively triggered to build cool things together. A digital lab where I can also decide the direction of topics important to the space. It would be like an alternative way to build my own community."*

Lastly, a participant explains that they would like to use this prototype to find testers in an organized way. They say that *"I can plan a bit in advance what I want to show and how many people I need. There might be some requirements for my test, like having knowledge about a certain topic. I would use this prototype to find people willing to participate in my experiments."* Additionally, they mention that *"I would also want to gather anonymous feedback. I feel like getting and giving feedback anonymously is easier, because someone maybe does not have the courage to tell you [in your face] that they do not like something."*

Problems in current prototype

The conscious decision was made to leave out certain biographical information in a learner's profile due to privacy reasons and unintended ways of using the VCS. This includes the name, age, and gender. One participant expresses that *"this would not be strange for me, at Design Lab when you just talk to someone, often it would be just about something they are working on. I would not start with asking how old they are or even ask their name."* However, another participant remarked that *"people need to have an identifiable ID, like a username. Otherwise for me, there will not be much of an added value. I need to have a reference point of past interactions, otherwise it'll always be random people in the virtual space."* Another participant says that *"it feels depersonalized if you do not see a name or a picture of the person. You don't know who you are meeting up with."*

One participant made a remark regarding the use of the Learning Hub. They say that *"I don't see myself scrolling for people to help, because that means I have to go in with the intention to help someone. For me, that is not a position I am in often."* They add that *"if there is a prompt in the prototype about something that really interests me, then I would be excited to help out with that."* This mentioned problem is similar to what another participant shared. They said that *"Design Lab used to have a white board where they would ask people that were there to fill in a form about a project that they were working on, or any skills or help they might need. The idea was that people would go to the whiteboard to find someone to help, but no one really did this."* The Design Lab attempting to implement a solution for connecting the learners more closely shows a need that the VCS could potentially provide.

The real challenge of this prototype is regarding the implementation, according to a participant. They explain that *"people would need an incentive to make sure that the content will be updated regularly. It would also need good integration with the space, like adding to existing channels."* They remark that *"the implementation of the prototype decides whether you can capture the value. The value is very dependent on the quality of the learners in the space."*

5. Final Design Concept

The Virtual Companion Space (VCS) prototype is, in short, an avatar-based digital platform, where each avatar in the virtual space corresponds to a person who is physically and presently located in a makerspace-like environment. This "virtual layer" on top of the physical space creates an extra overview of the learners in the space, especially about their interests, projects, and learning intentions. Feel free to explore the prototype with the following link. The prototype is created to (1) increase the access of the available knowledge in the space, and (2) encourage people (who do not know each other yet) to interact (in real life) with one another based on similarity in topics regarding projects, learning goals, and interests. In this chapter, we explain the VCS in broader detail. In figure 3 you can find a complete overview of all the components within the VCS prototype. For clarity, the overview is based on two individuals for simplicity in visualization. However, the prototype is intended to be used by all learners within a learning space. In the following sub-chapters, we zoom into specific components of the VCS overview, starting with the basics.

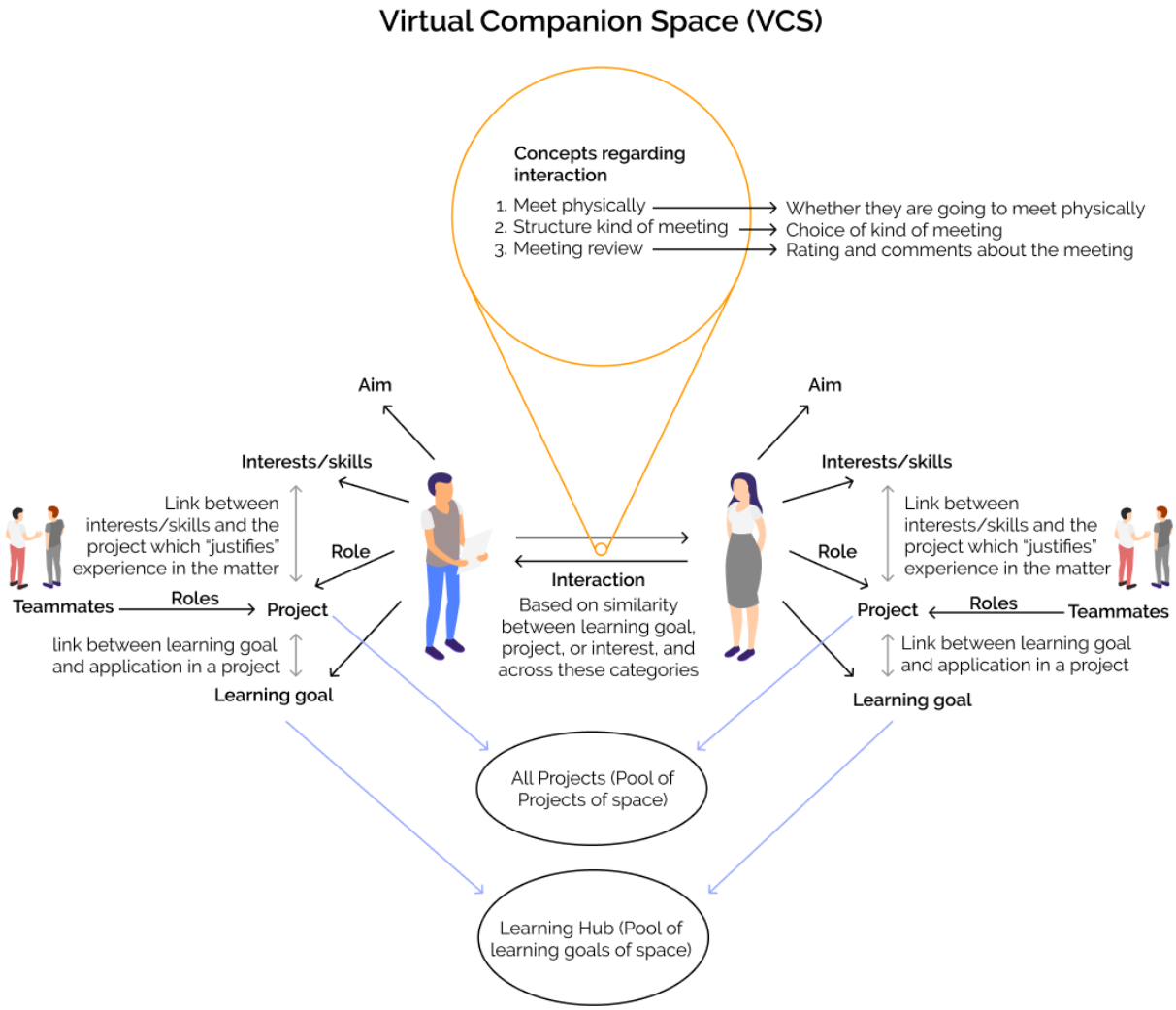


Figure 3 - Overview of Virtual Companion Space

5.1 The basis

At the core of the VCS prototype lies the facilitation of interaction between people in a PLE, especially facilitating the initial contact. One important insight from the qualitative data is that people do want to interact with those with similar interests, but do not initiate the interaction because it feels like a "shot in the dark". Before greeting a stranger and asking “so, what are you working on?”, you do not know whether there would be a "click" between you. Hence, people are less likely to initiate contact with someone they don't know in the first place, missing out on a possible fruitful connection. With this prototype, learners can find a good reason to initiate an interaction, whether it is about an interesting project someone is working on, someone asking you for help in a topic you are knowledgeable about or see if you can gain some insight by how someone else has approached their project. In Figure 4 you see a visual overview of the basis of the prototype.

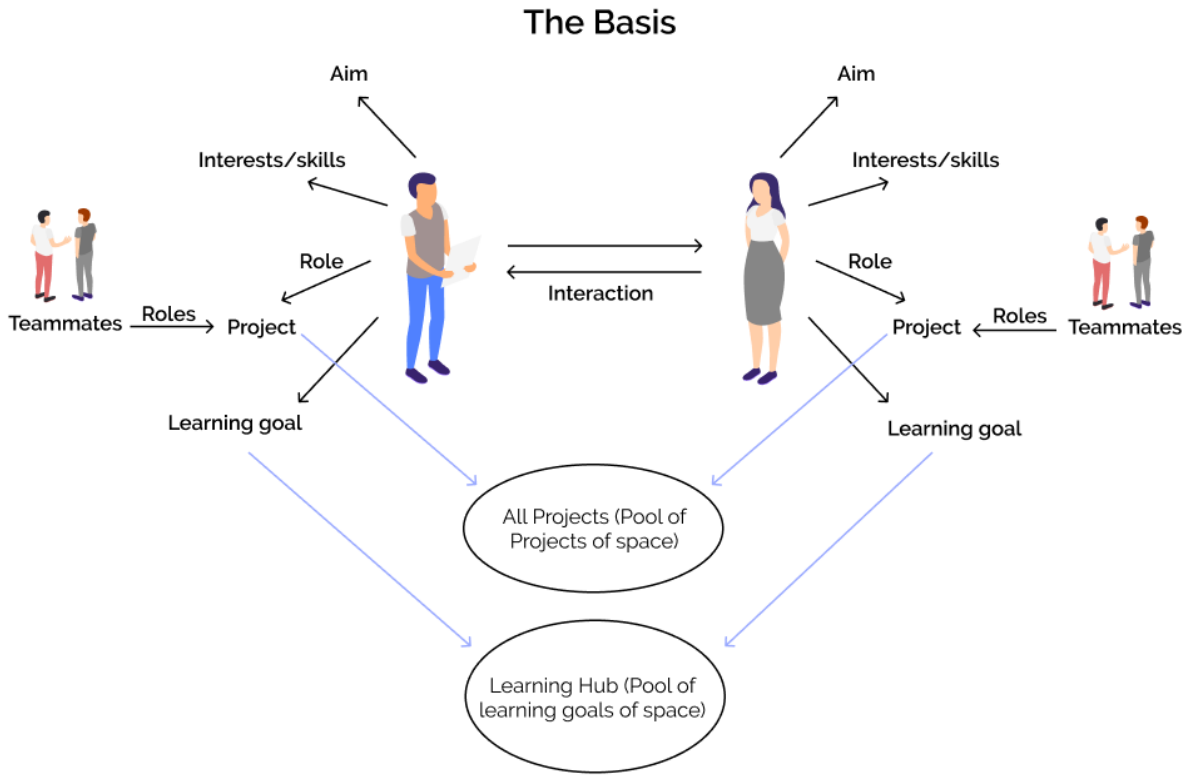


Figure 4 - Basis of VCS

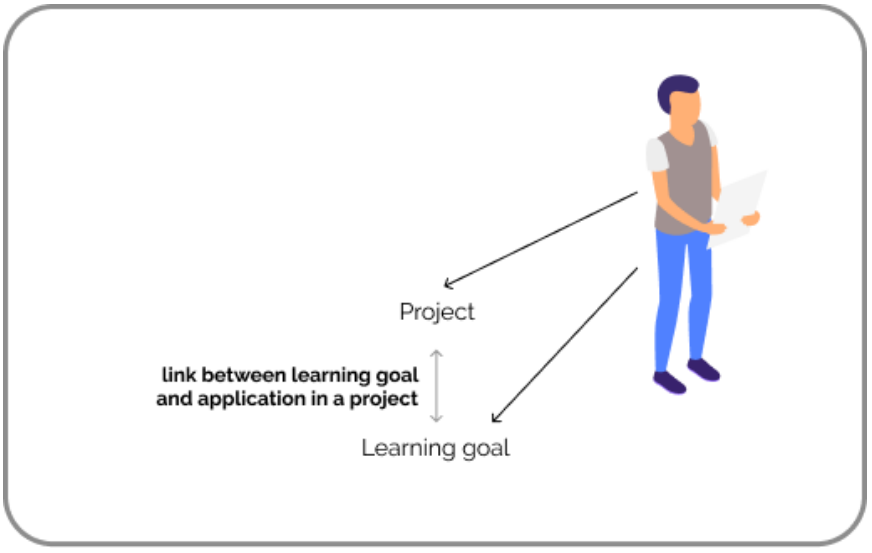
The basis of the prototype consists of several elements. First of all, Figure A1 in the appendix shows the starting screen of the prototype, showing the virtual environment with the accompanying characters corresponding to who is at the moment physically in a PLE. It is important to note that the exact location of the person is not depicted here, but merely an indication of their presence in the physical space. Each character has its profile, as depicted in Figure A2. Notice that the profile does not focus on demographic information but rather specific information, such as a person's

interests/skills, projects, learning goals, and aims. This is visualized in a way to represent the whole person with the head, heart, and hand, and (ideally) align those towards a vision that they 'see' with their eyes. Each learning goal or project depicted of all the characters is aggregated in the project overview (figure A3) and Learning Hub (figure A4). An example of a single project description is given in figure A5. In the project description, you can also find the teammates of the project with their roles, and a roadmap of what has been done, where they are now, and what are the next steps, to create a better context surrounding the project.

Notice that in the character profile, project description, and Learning Hub, the main call to action is to initiate contact by messaging (message bars). Learners can choose who to contact, based on the content given regarding projects, interests, and/or learning goals. Most probably contact will be initiated between those with a certain similarity in topics. For example, when someone is working on a project to craft their desk, someone else who is working on a similar project might start initiating contact for a question, advice or just to get to know someone else with a similar interest or goal. Another example would be if someone had a learning goal for business development, and sees a person with a start-up project. This person might ask for some kind of advice, guidance, or perspective.

In short, the basis of the VCS concept creates an overview of information about learners in a PLE, while encouraging interaction based on this overview regarding people's interests/skills, projects, and learning goals. This is an attempt to increase the accessibility of knowledge in a space. On top of the basis of the VCS, several additional concepts have been created that work towards the same purpose, described in the following sub-chapters.

5.2 Linking learning goals and projects



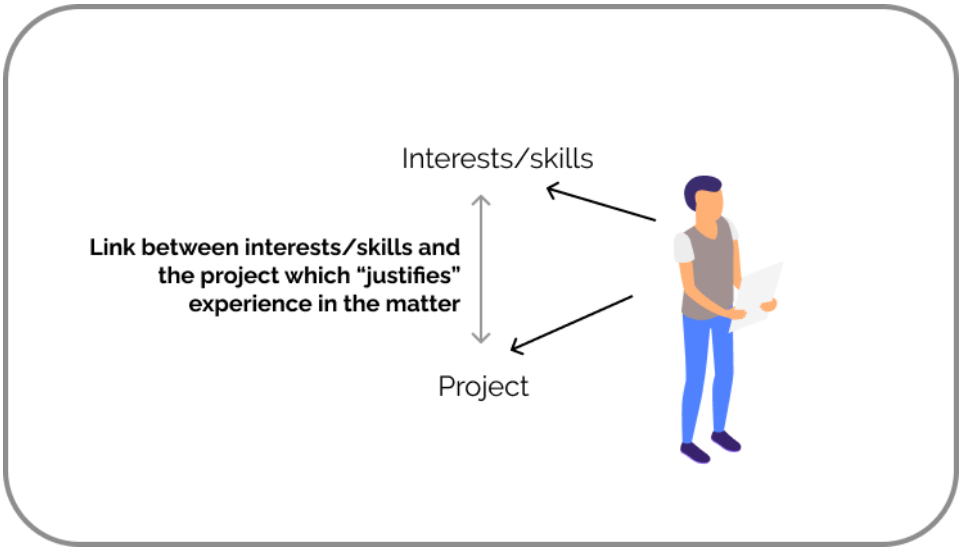
Learning goals represent an aim and desire to learn something specified. It is a way to signify to others that you are aiming to learn something, whether it is programming, Spanish, business development, or any other topic. One thing the learning goal does not tell you is **how** someone is learning it. In the spirit of 100ideas and their emphasis on applied learning, so too does the VCS make a connection between learning goals, and how they can be learned by applying them in a project. Therefore, it could be valuable to know which learning goals are linked to what projects.

In one way, this tells the person creating a learning goal that, a way to learn this goal is by starting a project about it. In figure A6 you see the UI of someone creating a learning goal. Here you see that you can link this learning goal to one of your projects. In figure A7 you see the UI of a learning card that is shown in the character profile and within the Learning Hub. Here you see that the learning goal is linked to the project "Sensors detecting movement", right under the card title.

Not only can one start a project as a means to apply the learning goal, the reverse can also happen. New learning goals could be started because of a project. While working on a project, oftentimes, some knowledge or experience is missing for you to advance. You might get stuck in your project because there is something you should learn first. If you can make explicit what you want or need to learn as a learning goal, you can start searching for someone who can help you out. How to search for the right person is covered in chapter 4.4.

The link between learning goals and projects can be fruitful when made visible and explicit. It insinuates that learning should not stay within the realm of the theoretical, but rather suggests that you can learn your learning goal through its application in a project.

5.3 Verification of skill

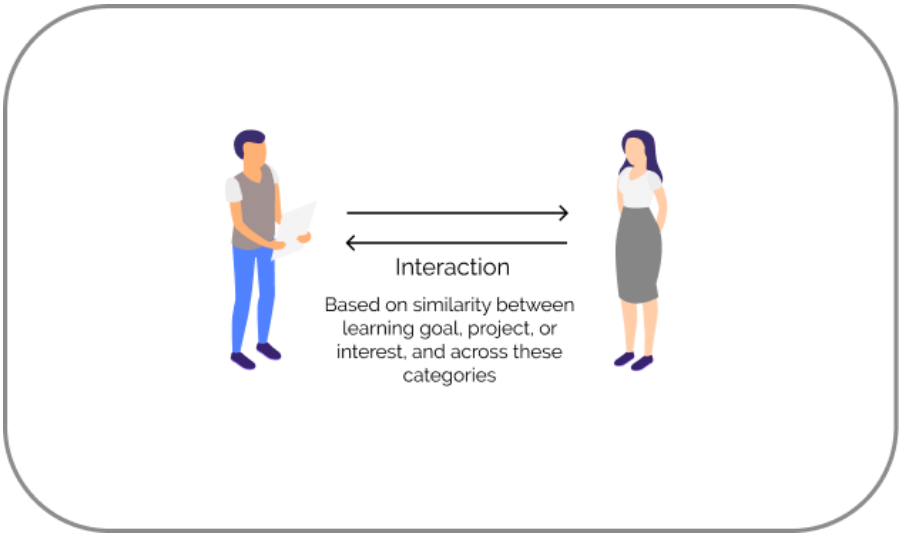


If someone indicates that they have a skill or are knowledgeable about something, how can one know that this is true? It could be the case that the person overvalues their knowledge and experience about a subject, without them knowing that they don't know much. They overstate what they know, and underestimate the things that they might not know. This phenomenon is also known as the dunning-Kruger effect (Dunning, 2011). What other ways are there to verify whether you have a particular skill or experience? One can perhaps upload certificates to legitimize their experience. However, someone might possess an abundance of knowledge and skill in something, without owning such certificates. Are we perhaps relying too much on certification? Perhaps part of the solution is not about stating that you have experience in something, but rather back it up with what you have done to prove it.

In the VCS concept, creating a link between skills and projects might give a hint about someone's experience in some topic. This way, someone can state that they have a skill in something, and to verify, it links back to the projects that show what someone has done. Past and current projects in this case are almost like a trail of experience. It is a way of trying to verify whether someone knows something by looking at what someone has done, and making this easily accessible for people to view. This can create a great overview for people looking for the right person to ask a question to or to ask to meet someone because their experience can help you learn and grow. One can ask more specific questions that are based on the projects someone else is involved in. Linking skills and projects can therefore be highly fruitful for increasing the accessibility of knowledge in a learning space.

For illustrative purposes, In Figure A8, an attempt is made to visually link the interests/skills with projects within the profile page. When you click on a skill, the skill button expands and shows in more detail what has been in terms of application of the skill.

5.4 Searchability of projects, interests/skills, and learning goals



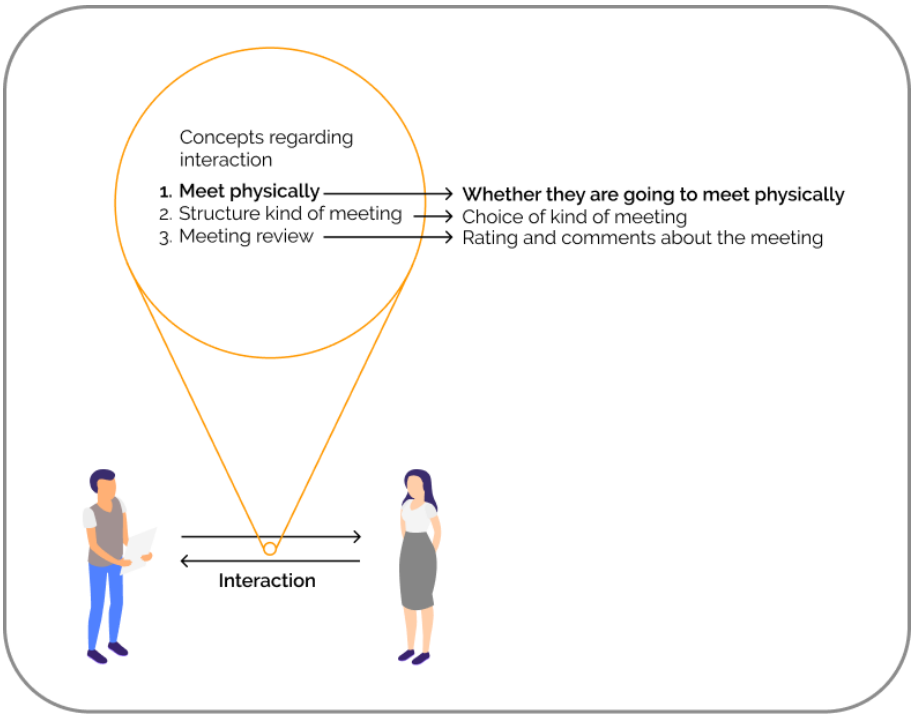
From the interviews, it was clear interaction rarely happens between those who do not know each other yet. So what is the reason to interact with a stranger in the learning space? It turns out that most of the time, there is not much of a reason to initiate contact out of thin air. How often would you go to someone who seems to be working on their computer and say hi, and ask "so, what are you working on?"

The VCS, with its increased overview of learners around you, shows what the reason could be to initiate contact. Abstractly, this reason is to find similarities in interests, projects, and learning goals. Practically, when I am working on a project, and I get stuck somehow, a good reason to initiate contact is to find someone who is working on a similar kind of project. Not only are people searching for similarity within a category (where "project" is a category), they also search for similarity across categories. For example, when someone has a learning goal (category A) to learn more about electronics, they might find someone who is working on a project (category B) that includes electronics. Similarly, someone who is looking for help in their project (category B) about a subject within psychology, might look for someone who has the interest or skill (category C) in psychology.

To make connecting with the right person efficient, learners should be able to find one another more easily. One way would be that all the interests/skills, projects, and learning goals get a tag based on the corresponding topics. For example, a project that involves business development can have the same "topic tag" as someone who has a learning goal to build a business. Although the tag "business development" is not precise because it contains many subtopics, there is still an opportunity here. The challenge would be to figure out what are the right kinds of tags, what is the level of granularity that can most successfully facilitate people finding each other when they are searching for someone.

An example of this increase in searchability based on topic tags is illustrated with the following concept called "question matching", seen on the UI illustrated in figure A9. This UI component is situated on the main screen. In this scenario, someone has a question. They type the question and add a few topic tags that are related to the topic of the question. A list of people appears that have these same tags, indicating that they might be the right person to ask your question to. You can then look into their profile to verify whether this person is the right one. Even better, perhaps we can identify the parts within someone's profile that are relevant for the question that one has, and show this directly. While this is one way of implementing some kind of a searchability system, there is much potential in finding better and more efficient ways in how searchability can be implemented and improved.

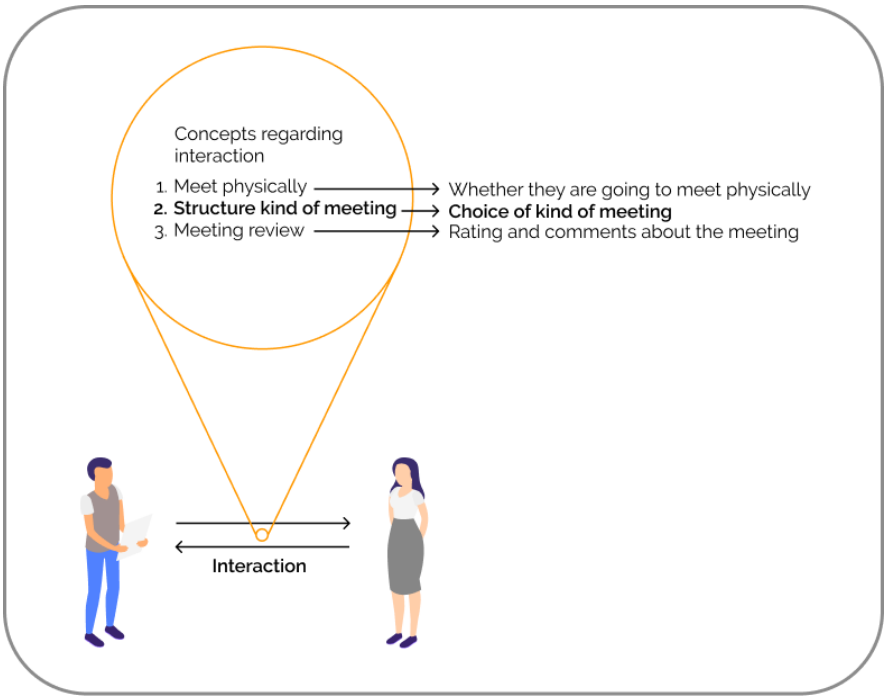
5.5 Encourage meeting physically



The VCS is not created to turn interaction between learners into virtual encounters only. On the contrary, it is created to attempt to increase the likelihood of learners interacting with each other in a PLE. We enhance these physical spaces by creating an extra overview of the people who are physically present.

Additionally, the VCS encourages establishing a meeting in the PLE that is tied to the VCS. Once it is agreed to meet with someone you met on the VCS, there can be a prompt to suggest a meeting in the physical learning space. Figure A10 illustrates an example of how this prompt could be given. In this example, 2 individuals agree to meet in front of the Design Lab. Of course, you can decide to meet somewhere else outside of the physical space. However, because all the visible avatars are already in the physical space, it would be more salient to just meet there. On top of that, there could be ways to integrate VCS into the physical environment as well. For example, by creating designated meeting spots to make it easier for people to find each other, or by adding a big screen that shows the VCS in the physical learning space, hinting to everyone that there exists a virtual extension to the space.

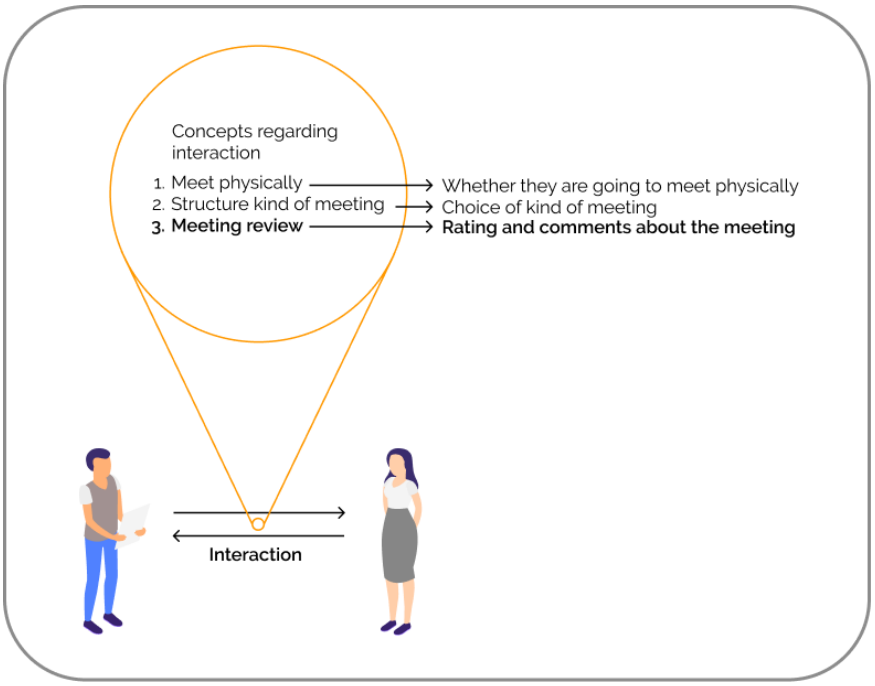
5.6 Suggest the kind of meeting



When you have communicated with another person (through chat), it might be time for you and the other to meet physically in the learning space. Meeting up with someone can be for several purposes. It could be because someone can explain some concept to you, or perhaps you just want to go grab a coffee? My question is, would the choice of the kind of meeting change when you provide options to choose from? These kinds of meetings become more salient to you merely because it is suggested to you. Perhaps, a suggested kind of meeting could result in a more fruitful conversation or interaction?

Figure A11 illustrates a selection of 5 kinds of meetings, which are, according to me, worth it to distinguish. The "how did you do it" focuses on tapping into someone's experience. Particularly of interest are stories of how they have applied things in their projects or other pursuits. Even better, they could demonstrate how they have done something, right in front of you in some cases, as some things can just not be explained explicitly. The Dialogue option emphasizes getting to a better understanding together around an issue, without the pressure "to be right". It is not about defending your position. Rather, people inquire into ideas rather than advocating for their own. Next is the "teach or advice" meeting, where you ask someone to teach you something you asked for. There is a slight difference between this option and the "how did you do it" meeting, where the latter focuses on giving examples from someone's own experience, while the former gives advice and teaches about something (for example, explaining some physics theory). The "coffee break" meeting suggests an informal meeting to get to know one another, perhaps because you are interested in each other's work. Any other kind of meeting can be chosen with the last “free” option.

5.7 Review system about the meeting



Adding a review system in the VCS can provide a great opportunity to know who has had quality meetings and why they were fruitful. The idea is to give out "helping hand" points when one has helped someone who approached them with a question or request for guidance. In figure A12 you see an example of the helping hand points being awarded to the person who has helped. In figure A13 you see a pop-up of how someone could give a review about the help that was just received.

It is important to note that the review is not "about" the person who has helped. It should not be a judgment on the performance of the person (e.g. whether someone is good at explaining). Reviewing the person can have negative consequences on the ecosystem of the VCS, such as getting a bad review while genuinely trying to help someone. The reviews should therefore not be displayed publicly. Rather, the review focuses on the meeting itself and whether it was a successful meeting. It is difficult to determine whether a meeting was successful. The idea in the current concept is to get a clue whether (1) the knowledge and experience of the helper was relevant to your question and (2) whether the person who has requested help has gained a new level of understanding on the matter. I do not claim that answering the question in figure A13 will capture the 2 stated points, it just merely gives a clue of how the person has experienced the meeting through their subjective eyes.

As an additional benefit to implementing a review system, 100ideas can identify those who often answer the call for help from others. Combined with the review specifically about the meeting, the helper can be an important node in the learning space who can spread knowledge and experience well. Being able to identify these people and recruit them in some fashion, benefits the whole

learning space. Also, when gathering many review entries from learners rating the help received, 100ideas can perhaps get a clue what might be the right kind of help, for what types of situations, or what kind of questions.

6. Data from the VCS

Figure 5 depicts a schema of the different components of the VCS that shows a flow of the whole process towards successfully meeting someone in a PLE. During this flow, different kinds of data can be captured as "by-products". In turn, this data can be utilized for the further development of 100ideas' Learning Analytics in physical environments. The schema is split between the (1) Overview Data, corresponding to the available data about individuals in a PLE, and (2) Meeting Data, corresponding to data regarding the run-up, establishment, and review of a meeting. The Overview Data corresponds to the concepts mentioned previously in chapter 4.1, until 4.3. The Meeting Data corresponds to the concepts mentioned in chapter 4.4 until 4.7.

When hypothetically, one captures the Overview data and Meeting data, what potential has it for the development of Learning Analytics tailored to physical environments? The potential can only be clear when it is aimed towards a specific goal. The goal of the VCS is to strengthen the connection between learners in a PLE to ultimately increase learning from each other. With this in mind, we can start looking at the data and how it can be used to get closer to this goal.

With the VCS, a whole new set of data comes free that is left untapped until now. Note that the Overview Data is considered to be the main resource to which people decide to either meet someone. It shows with whom one can have a potentially fruitful interaction, where some form of knowledge transfer can occur and is deemed valuable by the user. For example, this could be someone showing you how to solder properly. Upon closer inspection, the Overview Data functions as a **pointer** of the “real” resources, namely that which can only be accessed and transferred when the learners meet with each other. For example, a learner initiates contact because a peer might know how to solder, but only when they meet can the peer demonstrate and teach how to solder. It would therefore be desirable to figure out how to increase the accuracy of these pointers. This might be possible with the help of the Meeting Data. Particularly from the data from the review of the meeting, we can get a clue whether (1) the pointer to the resource was accurate and (2) whether the “real” resource was tapped into and therefore, new levels of understanding have been gained by the learner. It is merely a clue due to the fact that the data about the review of the meeting is based on the subjective account of the learner. Nevertheless, with this data, one can perhaps get closer to understanding how to increase the accuracy of the pointer to the resource, and how to increase the effectiveness of the knowledge transfer between the learners in a PLE. The subjective meeting review data about the accuracy of the pointer to the resource also has an influence on determining what is the right level of granularity of the topics tags. Which in turn (hopefully) increases the effectiveness of learners finding the right peers for some form of knowledge transfer.

Another potential is the ability to see who shows a propensity to help others in their learning journey. Someone who helps out and increases the level of understanding of certain topics for their peers. It might be that this person is very knowledgeable, or that they have an inclination to do a good job at helping the other gain a better level of understanding. Whatever it is, much can be learned from such people in terms of how to help others, and perhaps, even be taught to others in the PLE to increase the level of support among other learners.

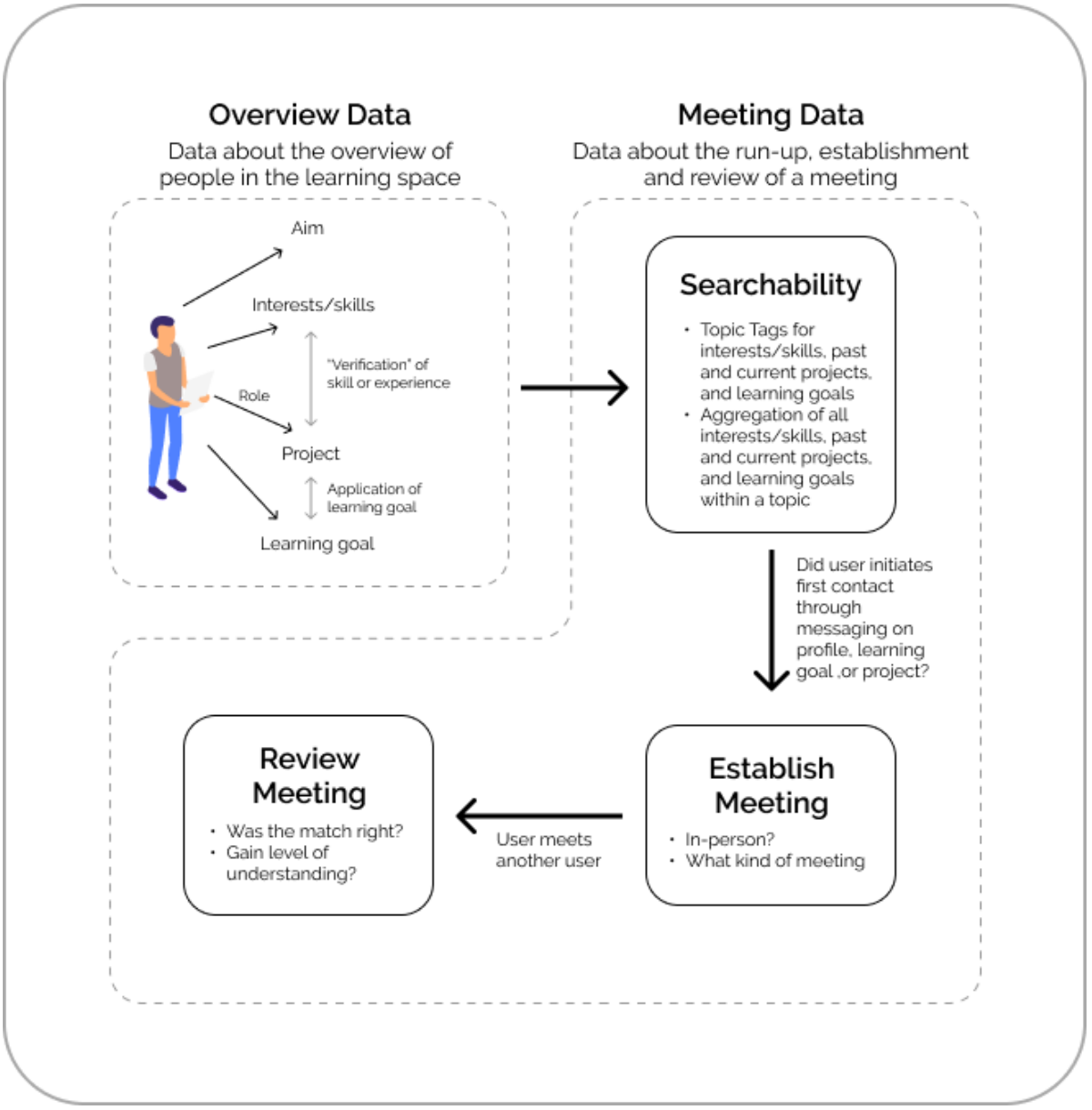


Figure 5 - Overview Data & Meeting Data

7. Discussion

This report has presented the journey of creating the concept of the Virtual Companion Space, outlining the design process, findings from the story interviews and prototype experiments, and analyzing the concepts' potential for gathering relevant data in PLEs. In this chapter, we will dive deeper into the role of the VCS in PLEs and how it can contribute to 100ideas' mission to improve face-to-face education.

To date, 100ideas is partly focused on developing learning analytic tools in PLEs. The approach is centered around gathering physical real-time data, which brings innovation to the learning analytics field, as current applications of learning analytics revolve around data gathering from e-learning on (web)-applications. While the application of Learning Analytics in physical settings is full of opportunities, little is still known about the social aspect of learning in PLEs. 100ideas is, therefore, determined to learn more about this social aspect through qualitative and quantitative data, to ultimately create the right tools to interpret the data correctly through Learning Analytics. Consequently, this leaves out the realm of how PLEs are used by learners in a day-to-day fashion since the social aspect is crucial. The VCS is an example of a design concept that operates within this realm.

So what happens on a day-to-day basis in PLEs? All participants have to some extent experience working in a particular PLE called the Design Lab. They have a workshop area with the typical maker-space equipment present and a large open area where students can work or study. The majority of the learners are working on projects individually or with their project members. During the experiments, it has been made explicitly clear that the VCS is meant to be "deployed" in a PLE, meaning that each avatar seen on the screen represents a person who is present at the PLE. On both experiment rounds, the highest valued aspect about using the VCS is the increase in potential fruitful social interactions with peers who did not have a chance to meet yet. The discovery of this perceived value was paired with the discovery of what social behaviors are taking place currently in a PLE. Possibly the majority of learners who go to a PLE usually only interact with people they know, and not those they don't know. This mostly includes interacting with friends and project teammates. This leaves out all the others with whom you potentially can establish a meaningful relationship. The gap between the perceived value of VCS and social behavior in PLEs shows a possible underserved need. Namely, that learners do want to connect with new peers, but approaching a stranger in a PLE is often like a "shot in the dark", that you do not know if the other person is interested in connecting as well, or whether there would be a click at all. Therefore, learners are less inclined to initiate social interaction with someone they do not know. The VCS provides learners with an overview of who these strangers are, based on their work or their learning goals. One can decide for themselves with whom they have a suspicion for a "click" based on this

information. In other words, the VCS has the potential to transform **initiating** social interaction in PLEs, where approaching a stranger is not anymore as a shot in the dark. Simultaneously, learners can now identify those people who could help you with a question, demonstrate to you how to do something practical, or with whom you can exchange perspectives regarding a certain project.

Take note that the concept of the VCS is not created to replace the PLE, as there are too many aspects of physical social interaction that cannot be mimicked on-screen. Rather, the VCS is an attempt to enhance the social aspect in PLEs. It should be seen as a second layer on top of the PLE that aids in establishing physical social interactions between peers. However, there is always a reason why peers decide to meet with each other, not just for the sake of meeting. This aspect needs to be carefully designed as well. There exist multiple social media platforms nowadays that connect people for all sorts of reasons, but only offer the allure of connection. Many of these reasons are not at all psychologically healthy for the user. In PLEs, a reason for one to connect with someone should be something that allows for some form of knowledge exchange. In the VCS, an attempt is made to provide this reason by capturing the learning journey of an individual, rather than, for example, sharing pictures of yourself during a holiday. The information available about a person consists mainly of (a) what the person has learned (the skills), (b) what the person aims to learn (the learning goal), and (c) how is someone applying what they are learning (the project). In an ideal scenario, one would want to integrate all these 3 aspects towards a personally meaningful aim. The content available on the profile of the learner tries to capture the work and learning which someone is engaged in, that is meaningful for them personally. It is the hope that, if people decide to initiate contact with someone based on their meaningful work, that consequently there is an increased opportunity for establishing meaningful relationships as well. This could be someone who has similar interests, someone who is like-minded, someone with whom you can collaborate on something jointly meaningful, or someone with whom you can share valuable learning experiences to learn from each other. It is assumed that establishing these meaningful relationships happens more likely when you meet physically. The choice of learners to meet physically is more salient because each avatar that is displayed in the VCS environment is someone present already in the PLE. Therefore, one convenient way to meet is in the PLE. This is in direct contrast to existing social media platforms that connect people across the globe, where meeting physically is not part of the focus.

Throughout this paper, the VCS has been created through a design process that ultimately only took qualitative data into account. We potentially discovered an underserved need that exists in PLEs like the Design Lab and provided a possible solution and value proposition. It would not be wise to, henceforth, rigidly stick to the underserved need or current value proposition and solution. These should flexibility change and be refined when more tests are conducted. In particular, quantitative data should be collected about what learners do when interacting with the VCS,

which bear many fruits for discovery. While the thus far collected qualitative data give clues about the value VCS can bring, quantitative data on observable behavior provides a more accurate account and validates what is valued. To get access to this type of data, a minimal viable product should be defined and created that provides the minimum amount of the value proposition. One should get the organization of a PLE on board for testing within the intended context, and see whether the value proposition can satisfy an important underserved need that ultimately is beneficial to the learner's (social) learning journey.

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9. Appendix

9.1 Figures of the Virtual Companion Space

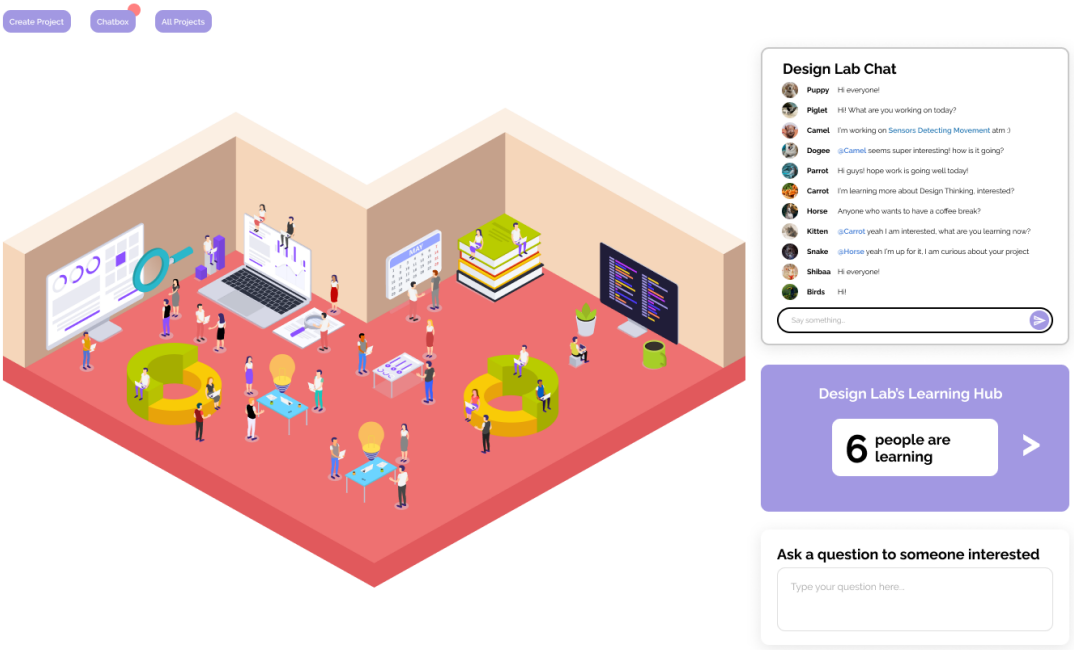

Figure A1 - Starting screen - virtual environment (back to text)

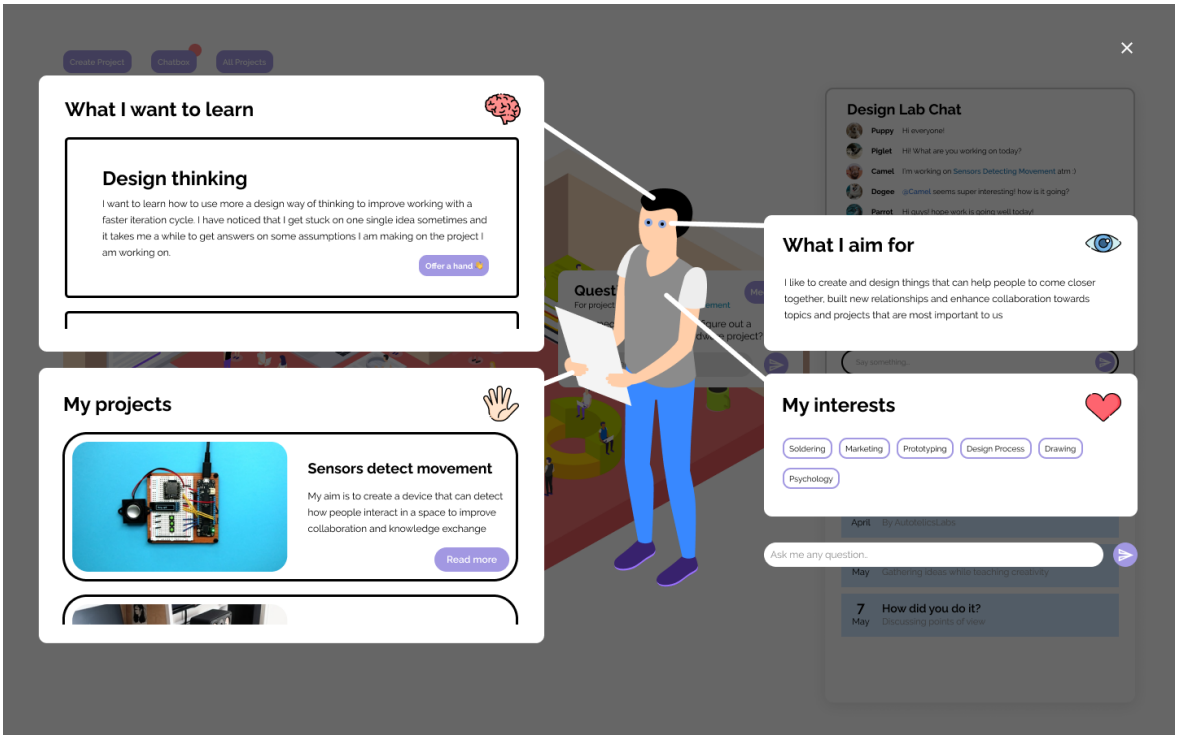

Figure A2 - Character profile (back to text)

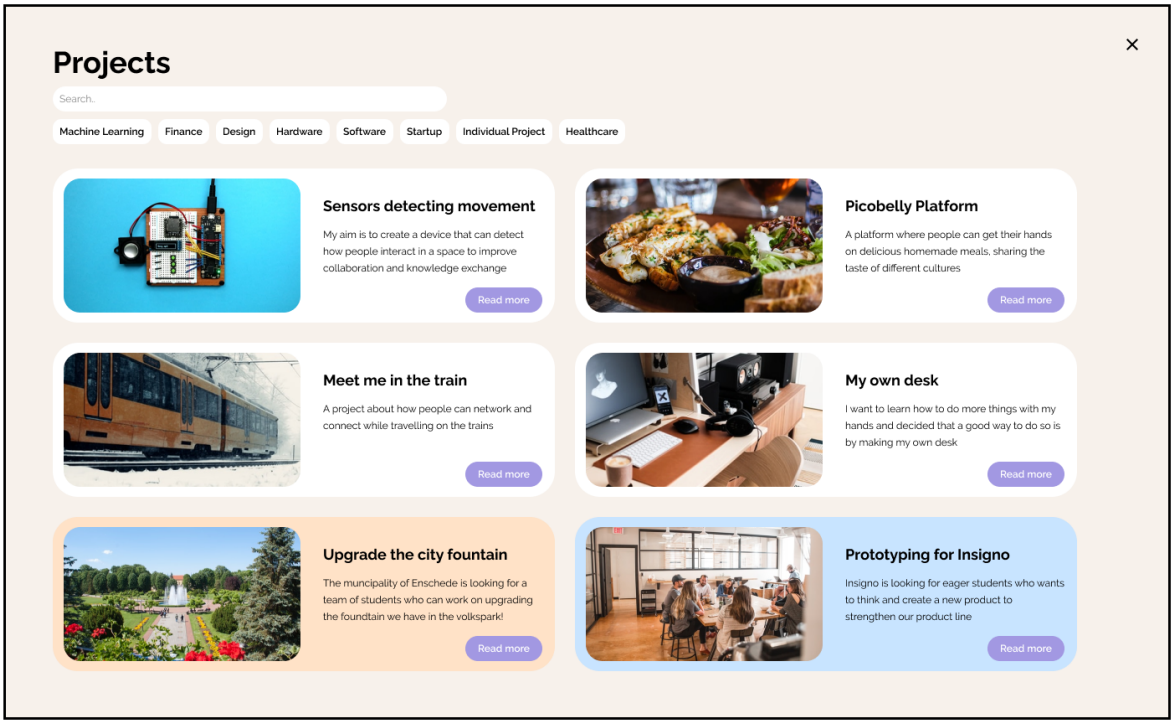

Figure A3 - Project overview (back to text)

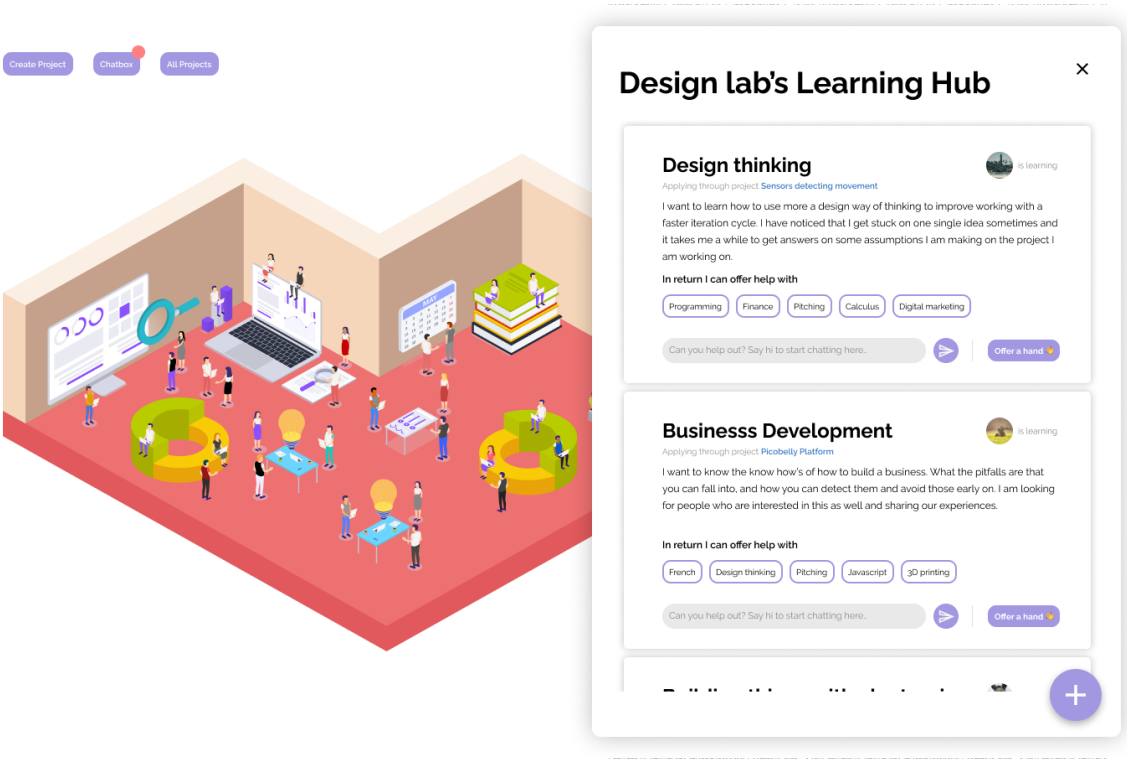

Figure A4 - Learning Hub (back to text)

Figure A5 - A project description (back to text)

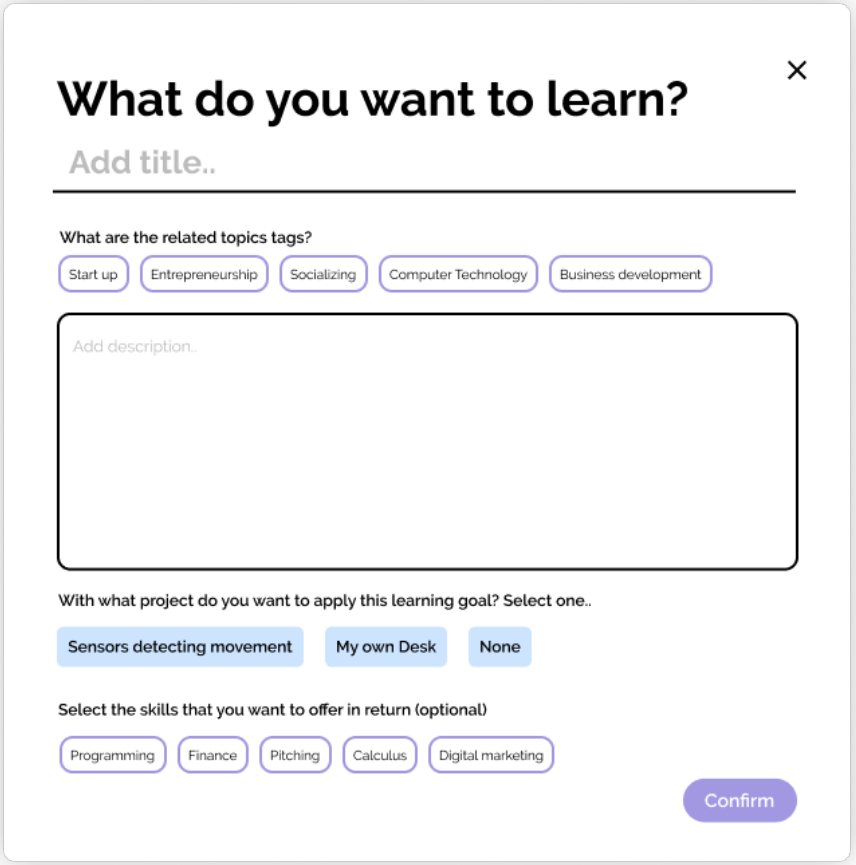

Figure A6 - Create learning goal card in the Learning Hub (back to text)

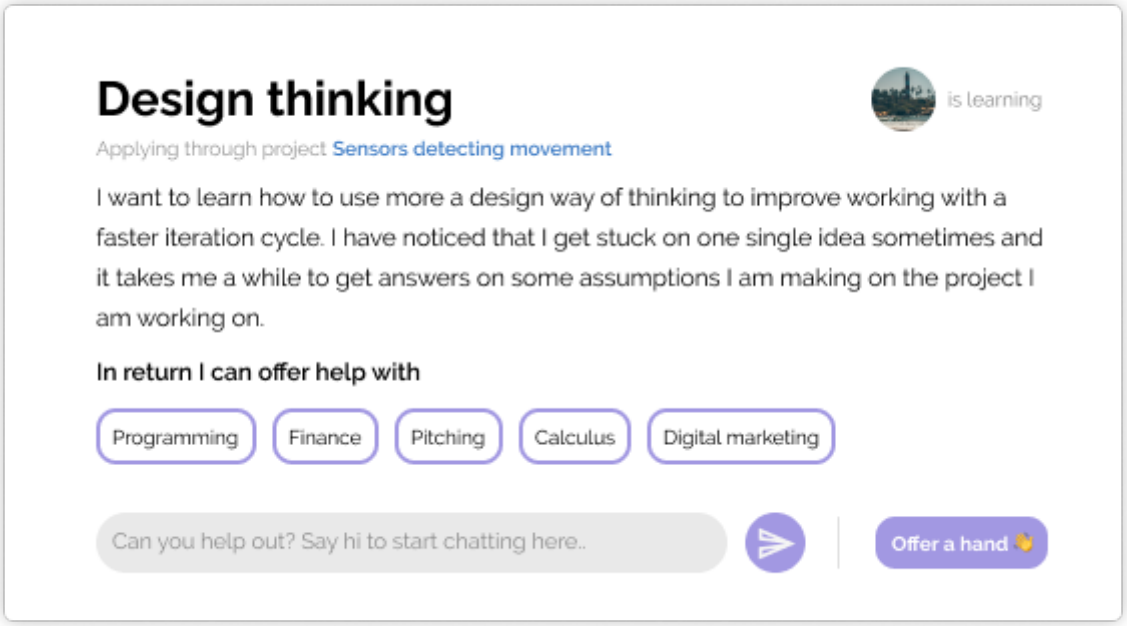

Figure A7 - Learning card (back to text)

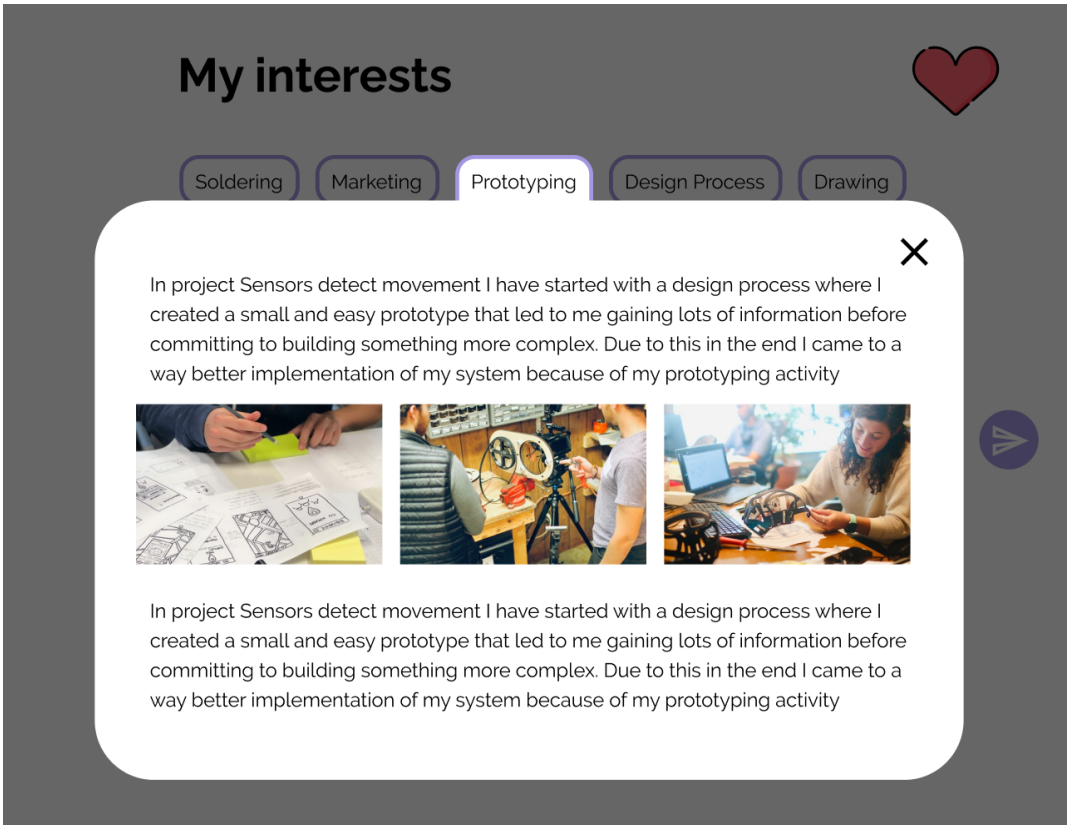

Figure A8 - Link skill with project (back to text)

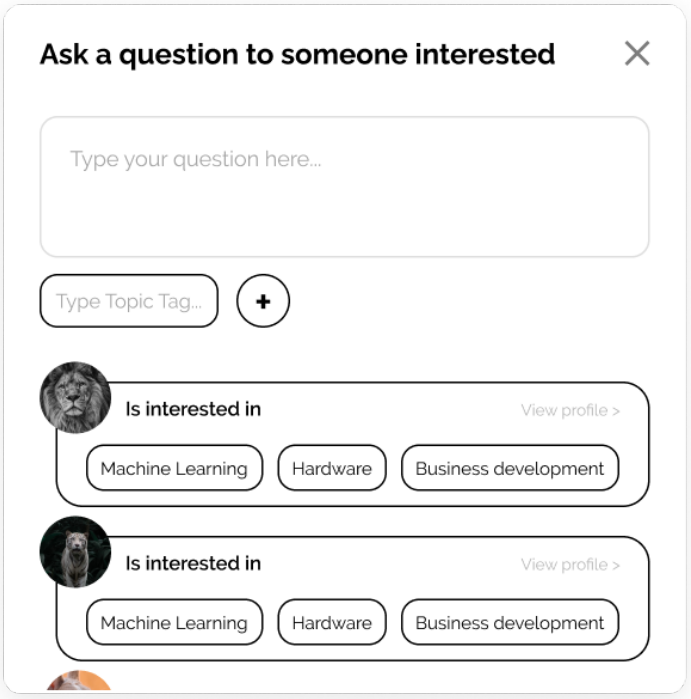

Figure A9 - Question Matching (back to text)

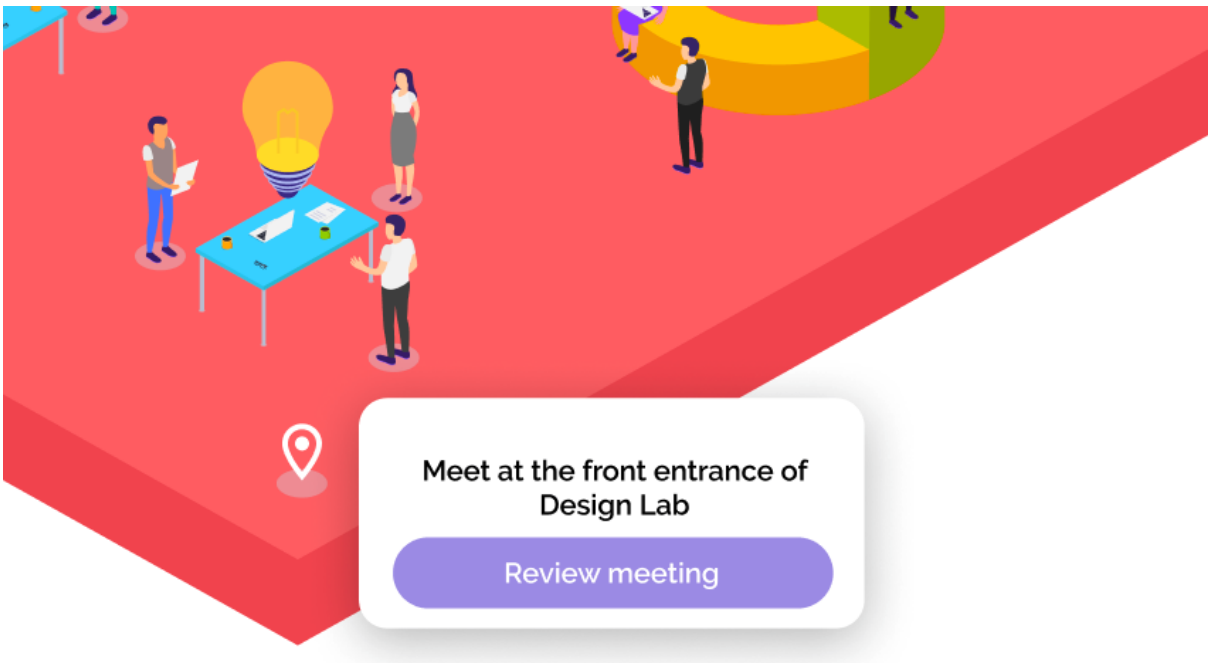

Figure A10 - Prompt to meet at the physical learning space (back to text)

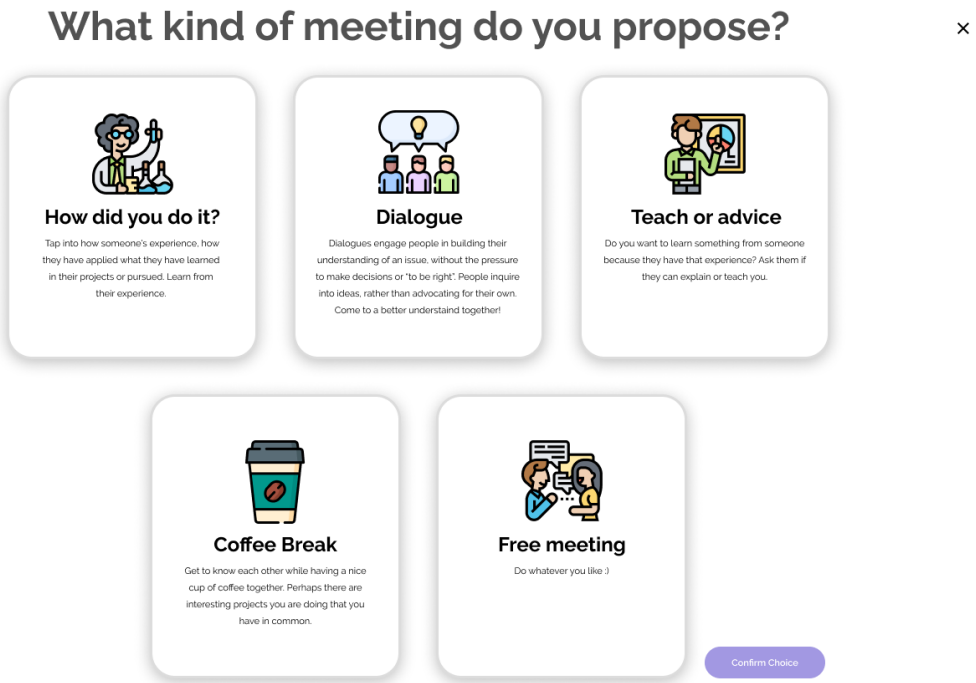

Figure A11 - Suggest the kind of meeting (back to text)

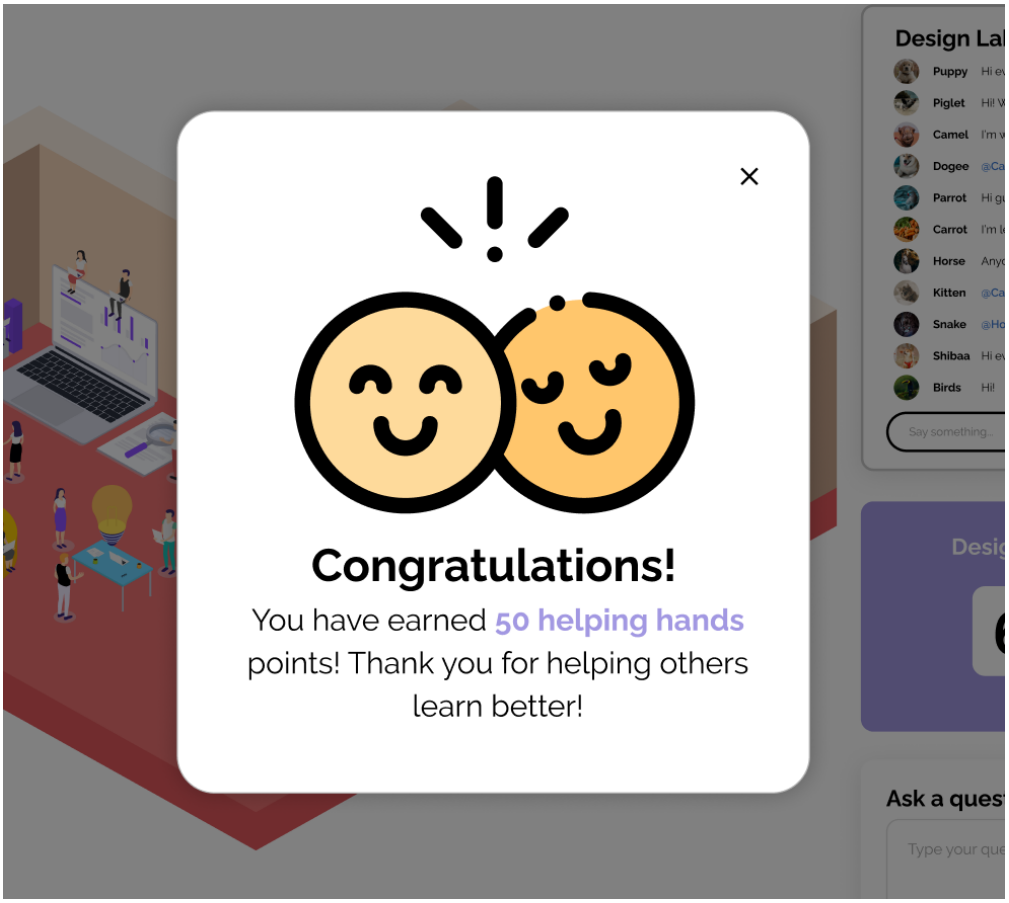

Figure A12 - Receiving rewards from helping (back to text)

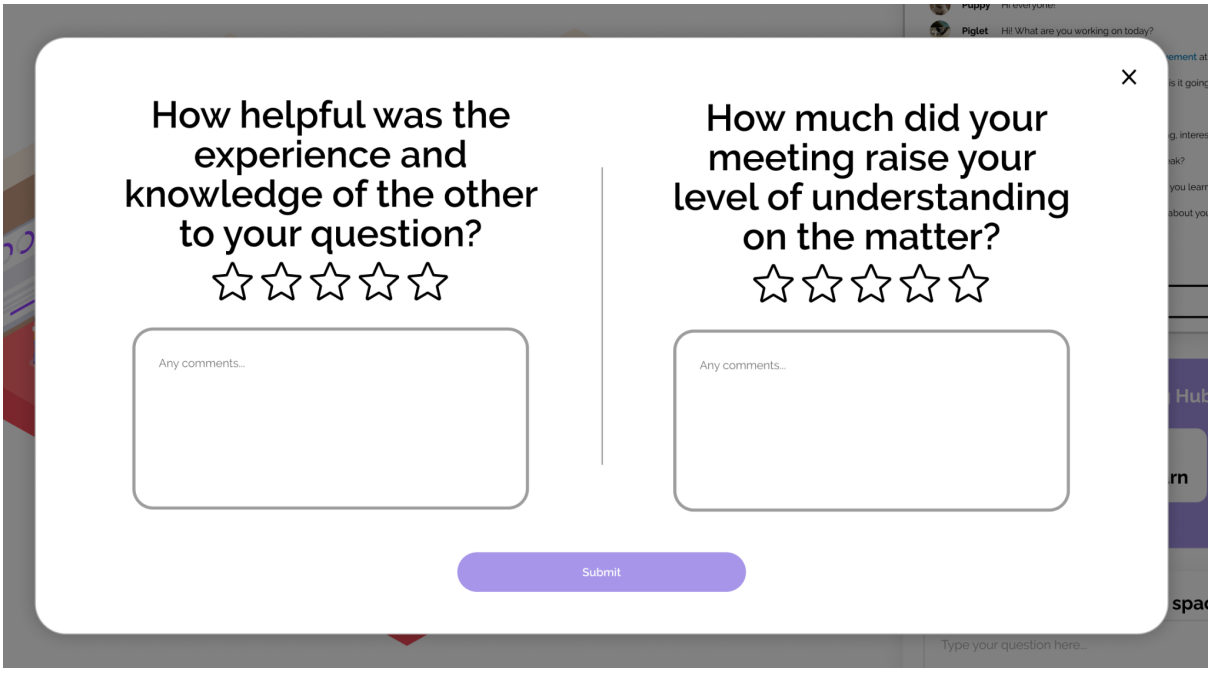

Figure A13 - Reviewing the meeting (back to text)