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PROTOTYPING - THE COLLABORATIVE MEDIATOR

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ABSTRACT
Given the potential to deliver 'future wellbeing products', learning mechanisms behind the establishment of such efforts is vital. In this scenario, early efforts are manifested in prototypes that concern ergonomic and innovative product features. Prototypes are made, presented and interpreted differently by people according to their understanding and frame of reference. Newness could interchangeably be used for prototyping as it unlocks cognitive mechanisms where embedded modes, e.g. visualization and communication, enable iterative learning loop in-between peers. The freedom of its use, which depends on contextual relevance and appropriate levels, is therefore important to be aware of. Looking at an ideal, prototypes should be equally strong knowledge disseminators in education as they acted upon in industry, but are they, and how could we expand our perspective on prototyping as a mechanism for creation? This paper investigates how prototyping allows new knowledge to emerge in its implicit role as collaborative mediator. The paper conceptualizes views on prototyping based on student's perceived learning experiences and lecturer experiences from engineering design projects. In contrast to past prototyping research, this paper establishes a link between knowledge embedded perspectives relevant for prototyping and its consequences for learning.

Keywords: Prototyping, collaboration, knowledge, learning

1 INTRODUCTION

Design education allows opportunities for students to better understand the depth and richness of user preferences that are involved in the process of prototyping [1, 2]. Creating tomorrow's products implicates that perspective taking is essential and concern at least two immediate influences on innovation. Firstly, to meet or go beyond explicit or implicit user demands and secondly for building wisdom and excel through learning experiences. This paper addresses the latter of the two where the variation in perspectives portrays prototyping as a collaborative mediator.

Prototypes can be roughly categorized into two distinct formats: physical and analytical [3]. Physical prototypes are tangible approximations of the intended product, whereas analytical or 'virtual' [4] versions are more commonly used to create a detailed and mathematically correct model of a specific product component. Virtual prototypes are flexible and easily modified which facilitates accuracy when adjustments are made to vital data needed for predictions, and thus assures confidence in the modelling process [4]. In contrast to reliability forecasting, many traditional prototypes still carry an important role of illustrating and communicating functionality.

Prototypes serve several purposes: they function as guiding milestones; show tangible progression or demonstrative specific features; and enable systems integration, ensuring components and subsystems work together as planned [5]. Prototypes externalize thoughts and make people talk, but the dialogues between people and prototypes is more important than creating a dialogue between people alone [6]. Depending on the type of design, prototyping can take on different forms and yet denote similarities in the final manufactured form. Prototypes allow ideas to merge in more comprehendible formats, and influence learning where existing and new technologies, routines and skills are integrated by problem-solving modes [7]. In consequence, the activity of *prototyping*, i.e. working with prototypes, has a central role in all phases of a product development project (e.g. viability testing, sub-system functionality, proof of concept).

For engineers idea generation and prototyping could very well be merged together as it allows various methods to be worked 'hands-on'. In parallel to idea generation methods, prototyping by definition manifests lateral thinking where divergence and systematic thinking is matched up [8]. Prototyping is an activity that supports areas such as idea generation, conceptualization, design exploration, evaluation, communication, and construction. Because it can be a massive undertaking to create a single prototype that strives to achieve all of these goals, it's important to be clear about your objectives. From an educational viewpoint, achieving learning objectives shadows the importance of performance outputs, although this often goes hand in hand. Past studies argue that reflections on the functionality; output use and role of prototyping in engineering education need greater attention [4]. In consequence, this paper builds on the presumption that prototypes stand the capability to merge collective context-dependent knowledge in engineering education.

Prototyping strengthen the collective knowledge that is present in organizations and groups through updates of new knowledge, and new methods for solving problems [9]. Leveraging knowledge production involves communication within and between individuals where a multiple communities of knowing exists [10]. Prototyping promotes a way of strengthening the unique knowledge of a community as it allows for perspective making (i.e. internal review) that in turn influences the communities ability for perspective taking (i.e. externally exposes and comparisons). The paper brings together several perspectives and summative experiences on prototyping - as collaborative mediator and supplement to already existing learning practices.

2 PROTOTYPING TO MANIFEST PERSPECTIVES

Innovation is characterized by breaking patterns; both by thinking differently and acting in new ways. Innovation literature [3, 8, 11, 12] tells that dedication to continuous learning and integration of prototyping activities is equally relevant as strategic implementation tactics to successfully build an organizational momentum. Shared learning and exchange of experiences across intra-organizational levels is seen as a way of assessing critical areas of improvement for the engineering role in industry [13].

Unlocking ways of thinking leveraging boundary objects is a natural innovative act, giving birth and rebirth to new innovative ideas. In this process, expansion of what is commonly understood is based on a fruitful communication and knowledge sharing. Arguments have been raised that this is manifested collectively by putting knowledge into context that has meaning verified by the participants accepting and using it [14]. Knowledge is proposed to be socially sourced and its construction mediated by social processes involving access to guidance, observation and interactions with peers together with workplace related artifacts [15]. Given knowledge social roots, the interaction between peers is crucial to create and reshape what could be manifested as boundary objects that allows for perspective taking and knowledge transparency overall [10].

Boundary objects are artifacts that coalesce a diverse set of physical and virtual entities and in a collective understanding [16, 17], and '*an object that lives in multiple social worlds and which has different identities in each'* [18]. A pragmatic perspective of knowledge and boundaries has arguably been helpful in explaining why knowledge is both a barrier to and a source of innovation and how knowledge processes enables learning, and transformation [17]. In the case of transforming tacit knowledge to explicit knowledge, for example, a prototype work as a common language capturing the expertise of particular individuals; thus, besides contributing to a common referral ground and 'organizational memory' it opens up endless opportunities for double loop learning to take place [19]. Based on double loop learning [20], the challenge and redesign of existing knowledge can reproduce changes to cognitive framing.

3 PROTOTYPING AS KNOWLEDGE DISSEMINATOR

The idiosyncratic model to prototyping is found in communication; sharing experiences, and in collaboration with others, building a thorough understanding of given ideas, concepts and range of feasible manifestations. Prototypes function as carriers of both stored and accumulated (i.e. dynamic) knowledge, thus the importance of transferring this knowledge becomes vital in all product development processes. Perceiving prototyping at a meta-cognitive level the externalization process follows Nonaka's argument: *'While tacit knowledge held by individuals may lie at the heart of the knowledge creating process, realizing the practical benefits of that knowledge centers on its externalization'* [21].

The kind of knowledge that is generated through this iterative work process has been addressed based on different taxonomic types [21, 22]. Different ways to formulate a knowledge sharing taxonomic approach is to identify specific conditions that facilitate knowledge exchange [22]. Prototyping is a unique process that encompasses a myriad of knowledge exchanges where learning aspects carry an important role. In trying to convey knowledge, it is necessary to understand the binary nature of knowledge; namely its objective and subjective components [23]. And its consensus/dissensus dimension existences that are oriented towards different scientific discourse: normative, interpretive, critical, and dialogic [24]. Prototypes are objects (virtual or physical) that shift in character similar to how knowledge representations are perceived to exist as objects; explicit or factual knowledge and tacit or 'know how' [25]. The fluidness of knowledge brings distinctive perspectives into dialogue through the construction and visualization of boundary objects [17]. Summarizing perspectives, several key words stand out. Key words that are well aligned with recognized knowledge creation modes [26]:

- working together, utilizing each other experiences and perspectives, integration and synthesis – *socializing*
- sketching, 2D and 3D representations, utilizing support instruments (e.g. SLS machines), rapid prototyping[1], functional and design features, numerous iteration, mental models, visualization – *externalizing*
- sensitive for recipients level of understanding, user need, correlation between output-input, verification, usability of content, delivery format or mode – *communicating*
- imagine, reconfigure, redesign thinking, reflection, pause, influencing decision making, sense making – *internalizing*

The above stated categorization underline a basis for product development processes in general, but also to the idea of using prototypes and the idea of redoing, reshaping, and reconstructing. Key words are undoubtedly contextually rooted, actions such as prototyping concern specific legitimacy for each context occurrence. Similar to the idea of contextual importance is also the underlying element of the SECI framework that explicitly emphasizes the essence of a common understanding to establish knowledge transfer.

The dynamics of knowledge creation and the need for a platform understanding or common view argue for a knowledge perspective to be in place to successfully enable knowledge transfers [26, 27]. The interrelation of individual and collective knowledge is proposed to be a generative source of accumulated successes, where stories and externalized means (e.g. prototypes) carry meaning to a specific group of people [28]. In this process inter-functional communication and co-ordination depend heavily upon the effectiveness of non-articulated translation and integrative procedures.

Similar to the anecdote of the knowledge iceberg [21, 29] where communicated and shared knowledge merely accounts for the visible surfaced representations, prototyping share this dualistic imperative. Collaborative and individual manifestations are dealt with in either virtual or physical shapes where the knowledge dealt with in one mode might be difficult to transfer to the next. However, iterations forming prototypes function as lateral manifestations towards perfection. This involve a combination of both 'explicit' collaborative learning aspects and hidden 'tacit' obstacles allow for intangible propositions to be processed, understood, and manifested to accompanying e.g. diversity and mutual understanding.

Prototyping allows surfaced knowledge to take part in the re-appropriation of, and as important function to means that ensure the integration of *sticky information* [30]. Given that prototyping should be perceived as a mean to interact, and an activity where a bundle of specific value creating meanings are attached, the enriching depth that prototyping allows must not be neglected or by any way disregarded as less important. Prototyping meets the requirements of lateral thinking, or rather creative and in many aspects functional communication.

4 PROTOTYPING FOR EXPERIENTIAL LEARNING

Experimental learning deals with conflicting dualities as complex mental processes is perceived and translated to knowledge categories: *active experimentation* and *reflective observation* [31]. Summarizing Kolb's ideas, active learners relate to testing beliefs through external methods and explanations in some way, whereas reflective observations involve examining and manipulating information introspectively. Active learners are experimentalists, and good in performing work in collaboration with others, whereas reflective learners are theoreticians, and like working by

[1] Rapid prototyping, focus on swiftness and basic level of representation (e.g. playing around with everyday material - paper, cardboard, duct tape, clay and Lego)

themselves or in micro format groups with just one other individual [32]. Indications say that engineers are more likely categorized as active learners [32], rather than reflective learners which correspond well into the role of an engineer, which is to engineer [33].

Reassuring proper understanding and application of prototypes target individual assessment and ability to learn. Individual learning and opportunity to ease in new methods or dealing with iteration processes set an important basis for establishing work conditions [34]. In similarity to past research [20], individuals will have learned but the organization will not have done so, prototyping intangibles are decoded and understood by individuals working together, yet knowledge constructs face disabled intra-group transfers limiting collaborative consensus.

Prototyping as a mean to evoke an action based knowledge state, or status of *'knowing in action'* [35] provoke different ways of assessing the role of what is known in an organization's ability to learn, to maintain quality, to develop competencies, and ultimately to innovate. The use of prototyping and tools that have an integrating function have from earlier research shown mismatch between application and specific tool functions [36, 37]. Therefore, to have successful use of prototyping it is essential to overcome obstacles and weaknesses involving individual learning, efficiency in task functional collaboration and work orientation modes.

In the daily workplace prototyping is an activity that can override dysfunctional communication structures, and aligning knowledge representations in a shared collective iterated representation. Methods and techniques that aid engineers in their daily work need early up front practice to have any considerable impact on work processes and target audiences. Prototyping in particular carries perhaps a greater value as knowledge repository than work practices is sometimes able to reveal. Without 'good enough' exploration of the design space in search for suitable alternatives subsequent design stages (e.g. analysis, testing, decision making) have no significant impact.

One key to bring about a reflective perspective and deepen the learning process for the individual would be to re-think and re-frame on-going negotiating design processes. Understanding about the learning process, how it works from a practical viewpoint, may substantially increase the chances of developing and applying these abilities later in life [6, 32].

5 PROTOTYPING ENHANCES PROCEDURAL KNOWLEDGE

Prototyping involves co-ordination of different knowledge types and levels, (e.g. formal/informal, local/global, tacit/codified, personal/social and software-embedded/people-embodied), where productive inquiries generate new knowledge and *knowing* [28]. In this process every *new item* refers to a new piece of knowledge and a *new way* that an individual decides to act upon relates to an individual's *knowing* [28]. Similar expressions in engineering education literature often use labels as *functional knowledge* [20], pragmatic *skills* [6]. Acquiring in-depth engineering skills corresponds well to what is claimed as *procedural knowledge* [38], where knowing *how* provides a basis for cognitive development.

The design phase is associated with several iterative loops that confront existing prefabricated knowledge expressions. To achieve optimized learning iterations each occurring loop opens up for new opportunities where surprising elements can appear. To transform a learning optimum knowledge transitions between the learner and the facilitator is to embrace a repertoire of learner's actions of re-framing, listening, reflecting, engaging in dialogue, and trying again [39]. The integration efforts by students working together are evident, as collaboration allows more of their colleagues' input into their own subsequent concepts. Vice versa colleagues also appreciate a more useful feedback to their creative thinking and prototyping efforts. In consequence, prototyping provide a tangible expansion to the generic understanding between interacting peers.

From an agent-based view, individuals learn as part of a greater facilitating environment, and as part of an organizational learning environment [40]. Our view is that this hub facilitates elements and distinctive actions (e.g. prototyping) that is transferable between the relationship a single individual and a collaborative team. The learning progression in this somewhat chaotic and iterative process underpins an engineer's pragmatic skills [33] and functional knowledge [36] through adaptive and renegotiable conditions.

6 CONCLUDING REMARKS

This paper presents multiple perspectives on prototyping and aim at providing a platform for deeper understanding of prototyping and its underlying implications in general. Independently of perspective taken, prototyping carries a unique and in some cases inappreciable position as learning mechanism; it combines knowledge, allow peers to interact and excel, and facilitates in-depth learning. As a collaborative mediator it could be argued that learning methods in engineering design should be flexible and balance along the axis of a duality optimum where on one hand; learning disposition shifts from more practical action based individuals embracing all sorts of prototyping challenges, and on the other hand; more theoretical, reflective individuals may need moments for thoughts to fully appreciate and incorporate the practical approaches involved with prototyping.

Allowing students to play with prototypes may capture the unexpected instead of confirming the findings of what is previously known. Engineering designers are continuously faced with new methods and tools to put in use. With shifting focus new aspects of product development indulge methods and tools to be matched up with suitable use. Prototypes provide illustrative examples on how product development teams form a common language and create knowledge about *implementation* as well as *applicability* of suitable methods and tools. Past research [20, 36, 37] indicate that practical knowledge, timely use, and reflective character of experiencing methods and tools use are vital ingredients for developing teams to achieve autonomy and integration functionality in product development.

This paper set out to link prototypes with cognitive augmentations where the founding belief is to adopt interplay between prototyping participants. The dynamism of knowledge (i.e. experiences and aptitudes) capsuled in boundary objects circuits around a shared understanding between interacting peers. As boundary objects prototypes goes beyond validation or verification they challenge existing beliefs and formulas. Through modes of communication, visualization and evaluation involved collaborative activities play pragmatically important roles in the function as collaborative mediator.

The way prototyping is perceived important as a collaborative learning tool for individual design practices opens up for more in-depth reasoning and questioning as to what extent individual learning is reassured and assessed through team-based prototyping, but this is beyond the scope of this paper. Our final remark concerns educational implementation of future prototyping activities, where versatile approaches can bridge individual creative and innovative predispositions and collaborative settings.

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