Designing Data-Driven and Adaptive Technologies for Reflective Learning in the Workplace

Viktoria Pammer-Schindler (aka: Viktoria Pammer)
OrCID: https://orcid.org/0000-0001-7061-8947
Habilitation
Graz, April 2019
Chapter Overview

**Chapter 1 – Introduction to the Habilitation** Lists papers on which this habilitation is based.

**Chapter 2 – Background and Motivation:** Starts with the foundational questions of what is meant by learning, what is specific to workplace learning and whether it is relevant, and what computer technologies can do for learning. From there, the discussion is narrowed down to reflection as means to learn from and through experience, and to designing data-driven and adaptive technologies for reflective learning in the workplace. The chapter also gives a first overview of own contributions.

**Chapter 3 – Related Work and Own Contribution.** Lays out the contribution of this habilitation to the fields of technology-enhanced learning and human-computer interaction. The chapter delves deeply into related work from these fields. Thereby, gaps in literature are identified, and contributions of this habilitation are concretised with respect to such gaps.

**Chapter 4 – Design-theoretical Considerations:** Summarizes design-oriented theoretical contributions. All such contributions are grounded in related literature and own empirical work. In short, these contributions are a concise terminology, patterns of iterations of reflection cycles in the workplace, and roles of technology and data in reflection.

**Chapter 5 – Socio-technical Interventions for Reflection:** Summarizes socio-technical interventions. Every intervention has been i) informed by reflection theory and related work, as well as own design-theoretical considerations, ii) iteratively designed and iii) evaluated in multi-week field studies in a workplace setting. Results from the field studies constitute evidence for successful implementation of the principle of using data as basis for reflective learning and for the viability of adaptive reflection guidance technology in workplaces.

**Chapter 6 – Discussion:** Constitutes a meta-discussion of own work, and draws a wider arch across individual previous publications.

**Chapter 7 – Outlook:** Points out next steps towards a vision of intelligent mentoring systems which encourage and guide reflection in an interactive manner.
# Table of Contents

1 Introduction to the Habilitation ................................................................. 7

2 Background and Motivation ........................................................................ 11
  2.1 What do We Actually Mean by Learning? .............................................. 12
  2.2 What is Specific about Workplace Learning? ....................................... 14
  2.3 Is Workplace Learning Important? ...................................................... 15
  2.4 What Can Computer Technologies Do for Learning? ............................ 16
  2.5 Designing for Reflective Learning in the Workplace .............................. 17

3 Related Work and Own Contribution .......................................................... 21
  3.1 Positioning in the Field: Design Science Research in Technology-Enhanced Learning and Human-Computer Interaction .................................................... 22
  3.2 Theoretical Considerations on Designing for Reflection - Related Work and Own Contribution .................................................................................................................. 26
  3.3 Technologies for Data-Driven Reflective Learning – Related Work and Own Contribution .................................................................................................................. 29
  3.4 Adaptive Reflection Guidance – Related Work and Own Contribution ...... 32

4 Design-Theoretical Considerations .............................................................. 37
  4.1 A Terminology and Cyclic Model for Reflective Learning ..................... 38
  4.2 Patterns of Iterations of Reflection Cycles ............................................ 39
  4.3 The Role of Technologies and Data in Reflection .................................. 40

5 Socio-Technical Interventions for Reflection in the Workplace ................. 43
  5.1 Research Prototypes .............................................................................. 46
  5.2 Activity log data as basis for improving time management ................... 50
  5.3 Mood self-tracking as basis for reflective learning ............................... 53
  5.4 Game Play: Reflection Guidance in a Quiz for Stroke Nurses ............... 57
  5.5 Computer Mediated Reflection Guidance ............................................ 60

6 Discussion .................................................................................................... 65
  6.1 Revisiting the Role of Data to Represent the Reflection Object ............... 66
  6.2 Sensitivity and Confidentiality of Data ................................................... 67
  6.3 Time and Space to Reflect ...................................................................... 70
  6.4 Expectation Management: Small-R Reflection, Or: When is a Tool for Reflection Successful? .................................................................................................................. 72
  6.5 What is Specific about Designing for Workplace Learning? .................... 74

7 Outlook: From Data to Intelligent Mentoring ........................................... 77

Appendix A Commented List of Own Publications ......................................... 79
  A.1 Own Publications .................................................................................. 79
  A.2 Editorial Work ...................................................................................... 84

Appendix B References .................................................................................. 87
1 Introduction to the Habilitation

The present habilitation is a cumulative habilitation in the field “Applied Computer Science” (as opposed to “Theoretical Computer Science”). It constitutes a summary and meta-discussion of work that has previously been published. All publications are peer-reviewed except for two that have been added for completeness (a book chapter - number 2; and a technical report - number 28). The peer-reviewed publications are six journal articles (J), eight conference papers (P), and the other 12 are demo, poster, works-in-progress, and workshop papers (WiP). The publications are contextualised within the field in Section 3.1 and are commented in Appendix A.


6. (J) Viktoria Pammer, Birgit Krogstie, Michael Prilla. Let’s Talk About Reflection at Work. International Journal of Technology Enhanced...


I contributed to the discussions, literature research, and paper-writing. The paper discusses the multiple roles of technology in reflection.


22. (WiP) Viktoria Pammer, Stefan Edler, Hermann Stern. Visualising the Fragmentation of Knowledge Work. Nordic Conference on Human-Computer Interaction, NordiCHI ’12, Copenhagen, Denmark, October 14-17, 2012.


2 Background and Motivation

Chapter Summary
This introductory chapter’s core statements are the following:

• Learning means a change of knowledge, attitude, perception, and behaviour through experience. Individuals, groups and organisations can learn. This habilitation focuses on individual learning; but highlights that in workplaces, individual learning is interwoven with collaborative and organisational learning (Section 2.1).

• Workplaces are a specific environment for learning, in that workplaces define the relevance of that which is learned, and in that workplaces are a priori not structured and designed for learning. This habilitation adds insights into specifics of designing for workplace learning to the field (Section 2.2).

• Learning in workplaces is necessary for individuals to be successful in their jobs, and for organisations to survive. In particular when changes are complex and unpredictable, informal and bottom-up learning as facilitated by interventions designed as part of this is necessary (Section 2.3).

• Reflective learning is a relevant mechanism for workplace learning as it directly refers to and impacts action without necessitating a curriculum or dedicated teacher (Section 2.5).

• Technologies can facilitate reflective learning. Conceptualising the relationships between reflective learning in the workplace and technologies is one contribution of this habilitation (Section 2.5).

• Data that represents relevant aspects of (work)life for reflection is assumed to be useful input to reflection based on work in educational and private life settings. This assumption has been transferred, in the present work, to workplace settings, and has been verified in multiple field trials (Section 2.5).

• Complementary support in the form of adaptive technologies that structure reflection (adaptive reflection guidance) has also been studied, and shown to be successful in multiple field trials (Section 2.5).
2.1 What do We Actually Mean by Learning?
This habilitation contributes an understanding of how people reflect and learn by reflection in workplaces, contributes concepts that are helpful when designing technologies for reflection in the workplace, and provides examples for such technologies that have been shown to be useful and supportive for learning in the workplace. But what do we actually mean by learning?

People understand different things when talking about learning, as they put emphasis on different aspects of learning, such as on who learns, what is learned, and what type of process or activities lead to learning.

Who learns – Individuals, Groups, and Organisations
The meaning of “learning” changes depending on which entity is regarded as that entity that learns: The individual human, a group of people (a social unit with which people identify), or an organisation (a formally structured group of people cooperating towards a shared objective). Depending on which entity is seen as the main entity that learns, there are significant differences in what is learned, how learning happens or how learning is intentionally brought about. Typically, without any further adjective, by “learning” we would understand that we are talking about individual humans who learn. Where this needs to be specified, this can be called individual learning, or human learning. When a group learns this is called collaborative learning; and when an organisation learns this is typically specified as organisational learning. Both the terms collaborative and organisational learning need additional clarification. The term “collaborative learning” needs clarification on whether the adjective refers to the entity that learns, i.e. a group who learns to work together or updates its shared understanding, or the process, i.e. whether one is talking about a group of people who learn together (cp. Dillenbourg, 1999; and Stahl et al., 2014 for a discussion of this distinction in collaborative learning). The term “organisational learning” means – in a first and circular definition - that an organisation learns. By organisation I here understand a stable, at least partially formalised, social system that is structured around overarching objectives and recurrent, similar tasks and activities necessary to achieve these objectives. Members of an organisations typically perceive themselves as a coherent social entity. Furthermore, organisations have defined procedures for decision-making; and most importantly for this discussion, organisations delegate authority to act on behalf of the collective to single individuals and hence include a system of roles and division of labour (cp. Argyris & Schön, 1996, p. 8ff¹). This means then, that also in organisational learning there are individuals who by their role and activity within the organisation enact the learning, and are therefore the agents of learning.

In own empirical work, individual learning has been the central goal of designed interventions. In addition, the impact of individual learning on the organisation has been considered in all field studies and evaluations of

---

¹ With respect to Argyris & Schön’s (ibid) terminology, I specifically mostly refer to the sub-types or organisations called “agency” and “formal organisation”.
interventions; and both theoretical and empirical work has highlighted the connection of individual learning in the workplace with collaborative and organisational learning (cp. Sections 4.2 and 6.5).

What is learned - Learning as change through engaging in real life
Learning of humans is essentially understood as a change in brain structure (cp. Spitzer, 2006). However, not every change counts: A change inflicted by an accident is certainly not learning; and neither are changes that are "natural" indicators of age – so deterioration in old age is not understood as learning process, and typically early child development is also not understood as learning. Instead, these are understood as developmental, maturing, or ageing processes. This means, that human learning is understood as a change in brain structure due to ongoing life and experiencing reality, i.e. through engagement in activities and participation in different social practices. At a higher level of abstraction than "change in brain structure", learning might mean a change in perceptions, attitudes, and knowledge (cp. Boud et al., 1985) of the human who learns. These in principle unobservable changes, even though they can be tested for. Alternatively, learning might mean behaviour change, which is observable. Of course these two kinds of changes are inter-related: Changed perception, attitude, and knowledge impacts behaviour; and changing behaviour may ultimately lead to different perceptions, attitudes, and knowledge as the experienced life changes.

For groups, by analogy, it is the core knowledge structures shared by the group or by the organisation that change, such as sanctioned perceptions and attitudes within a group, and shared knowledge and best practices. In more formalised organisations it is the knowledge base in the form of explicitly documented knowledge and organisational processes, and implicitly available knowledge via personnel, organisational culture, and shared practice that change (cp. Nonaka, 1994; Argyris & Schön, 1996, Ch1).

This habilitation explores learning from the perspective of individual learners in the social context of organisations. Therefore gained knowledge and changed work practice are core concepts that are used to evaluate interventions that have been designed and evaluated as part of this habilitation. In addition, due to the strong connection of individual learning and organisational learning in the workplace, also impact on the organisation has been a core concept in evaluations (cp. introduction to Chapter 5, p.45).

How Learning Happens – Processes and Activities for Learning
Finally, one of the most contested issues in learning sciences is how learning actually happens. The understanding of the process of learning, or activities carried out with the purpose or the result of learning is a significant differentiator between different nuances of what is meant by learning. One key dimension of differentiation is whether learning happens as formal learning (with a set learning goal, such as in schools or universities) or as informal learning (where the main goal of activities is something different than learning). Another key dimension of differentiation is who participates in
learning: When learning is to a substantial degree driven and organised by the learner, one typically talks about self-regulated learning; when a senior person accompanies learning one may talk about mentoring, coaching, training, or teaching; and when multiple people learn together, one may talk about collaborative learning, or about group learning. Intentionality is typically not required for something to count as learning; something that is especially obvious in informal learning settings (cp. e.g., Eraut, 2004); and intention is definitely not required for a change in brain structure (cp. Spitzer, 2006). There is however an understanding that some activities are designed for learning, while others are not. In particular in the context of workplace learning, many activities through which learning occurs are not designed with learning as primary goal.

Many learning theories can be differentiated according to their conceptualisation of sub-steps in the learning process, such as behaviourism understanding learning as learning responses to stimuli, and constructionism understanding learning as knowledge construction process (that everyone needs to go through on their own, at the extreme). Other learning theories can be differentiated by which aspects they emphasise as important for learning, such as reflective learning (cp. Boud et al., 1985), experiential learning (cp. Kolb, 1984) or social learning (cp. Bandura, 1971). Learning theories in turn influence on what is understood as a well-designed learning and teaching process and environment; or if intentionality is not in focus what is understood as processes and environments conducive to learning.

This habilitation mostly explores informal learning in the workplace. As part of this habilitation, interventions have been designed that make learning from experience intentional by stimulating reflection, and that connect formal learning to experience by stimulating reflection (Chapter 5).

2.2 What is Specific about Workplace Learning?

In the research fields of technology-enhanced learning (and in extension in human-computer interaction), workplace settings constitute a sub-group of settings for learning and using technologies as tools that aid learning. It may be asked, whether workplace settings are fundamentally different from other settings of learning, such as learning in schools, at university, or in private life. To some extent of course, every workplace setting is special, and different workplaces may differ from each other very significantly in size, in degree of formality of procedures and hierarchy, in infrastructure, in organisational culture with respect to learning and making errors, etc. The below description of specifics of workplace learning is therefore not a description of characteristics that are true in every workplace settings, but are plausibly found in many workplaces.

Workplace learning means that learning relates to work, such that it encompasses all learning “needed for successful performance in an occupation” (Hager, 2011, p.17). Workplace learning mostly comes with the implicit connotation of relating to work within organisations; and mostly, work is understood to be paid. This is also the understanding I follow in own work.
The major a priori difference between learning in educational settings and workplace learning is the learner’s engagement in work, and in learners’ motivation in learning because of work. This seems obvious; but it implies that it is the social context of work that defines the relevance of that which is learned, and poses constraints on what may be applied and subsequently learned sustainably, as the learners act within a set of rules, roles, divisions of labour. In addition, this social context including its overarching objectives and tasks and activities is not designed for learning. In other words:

Organisation’s value-creating processes typically have nothing to do with learning per se - most organisations’ overarching objectives are not to learn but to produce something or to provide a service of some sort, and thereby to make money. Consequently, within the social context of organisations, priority is therefore frequently assigned to operative work (as opposed to learning); and most relevant for reflective learning: Roles and a division of labour impact who can apply (individually gained) insights or who can engender organisational learning.

Through own design and empirical work, I am able to add insights on what is specific about workplace learning, in particular in relationship to technologies for data-driven and reflective learning (Section 6.5).

2.3 Is Workplace Learning Important?

Workplace learning is inevitably part of every workplace. Humans inevitably learn in the face of ongoing, and of course in particular in the face of novel, experience (Spitzer, 2006). Naturally, learning could also simply be valued for the joy it brings to know more and be capable of more (Spitzer, 2006).

However, in knowledge-intensive workplaces and positions, learning is inextricably linked to and constituent part of working (cp. Kelloway & Barling, 2001). In such workplaces and positions, the problems that are worked on is by its nature complex, changing, and new every time they are addressed. Such problems have been called “wicked problems” (Ritter & Webber, 1973). There is not a single suitable response to a wicked problem, and subsequent problems are always different and require in-depth interaction by responsible persons again. In other words: Complex, “wicked” problems require responsible people to continually learn and update their perceptions, attitudes, and knowledge. Hager (2011) summarises this perspective of learning as preparation for and reaction to external change as “learning as an increasing capacity for acting in flexible, constructive and innovative ways appropriate to the challenges of ever-changing circumstances” (ibid, p.14 online version). Many workplaces experience such dynamics: Workplaces change due to globalization and technological changes (not only IT technologies). As a consequence, work has become more specialized, hence more collaborative and networked; more global, hence more distributed; and more independent of time and space due to affordances of new technologies that allow for instance for remote and home work.

In the face of such a dynamic environment, learning is necessary for individuals to be successful in their jobs, and for organisations to survive (cp.
Burnes et al., 2003; Hager, 2011; Littlejohn & Margaryan, 2013). In addition, when changes are complex and unpredictable, it is important that formal, top-down organised trainings are complemented by informal, bottom-up driven learning in order to respond fast to novel circumstances, and in order to push insights from operational to management and strategic levels in organisations (cp. especially Burnes et al., 2003). So beyond workplace learning just happening, in an unavoidable, continuous and richly varied manner in parallel to working, workplace learning is also important; and informal and bottom-up learning in organisations in particular is necessary in order to deal with the environment’s complexity and dynamic.

Own interventions support precisely this informal learning that enables bottom-up learning in the sense of constituting the starting point to communicate problems and insights further within an organisation; and empirical work shows that this opportunity has also been taken up in different cases (as in the example discussed in Section 5.3, p.55ff). Further, own theoretical work provides terminology for talking about patterns of such connections between individual, and group/organisational learning; and has identified related communication patterns (cp. Section 4.2).

2.4 What Can Computer Technologies Do for Learning?

Very naturally, in a world pervaded by computers, these are used in a variety of functions to support learning. Technology shapes the activities that are intended to lead to learning; and can aid in manipulating and updating explicit knowledge structures that are external to human brains such as a digital knowledge base.

Below, categories of technologies are listed that are used and researched as aiding learning2. The categories are not mutually exclusive. For instance, technologies that support the consumption of digital learning materials might as well be game technologies; and simulations may also support communication, etc.

Additionally, while categories are intended to be exhaustive, in detail one could argue about additions to the list of categories. One such additional category might be “open learner modelling” in data analytics and intelligent systems, which in the end has been decided to be a more fine-granular term than the others in the list). Another example category that was ultimately excluded from the list is e-Assessment, which has been left out as simple question-based assessment is technologically not research-intensive, although it may be very much from a learning sciences perspective!. On the other hand, task-based or implicit assessment fits into multiple categories such as game technologies or virtual simulations or data analytics. Finally, infrastructure and device technology necessary to actually access content and

---

2 This subsection on the role of computer technologies for learning has been shared as blog-post at the time of finalising this habilitation thesis. The reason I shared this text is, that there is no such overview published that I know of that would be helpful to answer just this question: What can technologies do for learning? [https://viktoriapammer.wordpress.com/2019/01/29/what-can-computer-technologies-do-for-learning-the-roles-and-functions-of-technologies-in-learning/]
run software for learning, such network infrastructures or mobile devices – even though these play a key role in enabling technology-enhanced learning – have not been listed at all. References, where included, have been selected to be relatively modern and introductory to the category.

- Technologies support the documentation of learning activities and results
- Technologies support the distribution and consumption of digital learning materials (including learning management systems, MOOCs)
- Communication technologies and social software features support discussions between learners as well as between learners and teachers (cp. Stahl et al., 2014).
- Virtual simulations support experimentation that is safer, sometimes cheaper, or even impossible in reality (cp. de Jong, 1991).
- Data analytics are used to derive insights about learning activities and results from all kinds of sources for a wide variety of stakeholders. This includes learners, who shall be supported in learning; teachers, who shall be supported in teaching; and institutions, who shall be supported in institutional decision making thereby impacting learning (cp. Siemens, 2013).
- Intelligent technologies proactively recommend learning materials and relevant people and guide learning activities in complement or as substitute to human teachers (recommender systems – cp. Manouselis et al., 2010; intelligent tutoring – see Baker, 2016 for a critical discussion that includes an overview of intelligent tutoring literature)
- Gaming technologies finally design for learning in a playful environment (serious games or learning games – cp. van Eck, 2006).

As part of the present habilitation, technologies have been designed, and positively evaluated in workplaces, that support reflection based on data and provide adaptive guidance for reflection. These technologies support the documentation of learning activities and results, support communication, collect data and implement simple forms of data analytics, and include functionalities that proactively remind users to reflect and point out particularly interesting data points.

2.5 Designing for Reflective Learning in the Workplace
The goal of research within this habilitation was to investigate technologies that support in particular reflective learning, as a suitable mechanism for informal learning in workplaces.

Reflective Learning
By reflection one understands to learn from experience by critically re-considering experience, and questioning one’s past behaviour, perceptions and own knowledge with the goal to improve some quality of future activities
and action (cp. Boud et al., 1985; Daudelin, 1996). In a word: Reflection is the intelligent way to learn from experience, beyond simple trial-and-error (although experimentation plays an important role also in workplace learning). Reflection can be very brief and embedded into action (reflection-in-action, Schön, 1983), or it can be more temporally separated from action (reflection-on-action, reflection-before-action, Schön, 1983). As reflection constitutes a learning mechanism that directly refers to and impacts action without necessitating a curriculum or dedicated teacher, reflection is a key mechanism for organisational learning; with Knipfer et al. (2012) going so far as to call reflection the driving force for organisational learning. Despite the relevance of reflective learning in organisations, there is very little knowledge about technologies for reflection in workplace settings outside this habilitation; and there are very few works in general who provide design-oriented theoretical considerations for designing for reflection. The contributions of this habilitation are situated precisely in this gap: They are i) design-theoretical considerations on designing for reflection in the workplace, and ii) examples of socio-technical interventions for reflection, which have been shown to lead to reflection, learning, and experimentation with new behaviours in field studies in workplaces.

Technologies for Reflective Learning
Reflective learning does not need technology; however, technologies can facilitate reflection. With this habilitation, I have contributed to highlighting the multiple types of support that technologies can give to reflective learning such as capturing and providing data relevant for reflection, reminding people to reflect, supporting collaborative activities related to reflection such as sharing and discussing experiences, structuring or guiding reflection, or providing means to document the reflection process. The present habilitation conceptualises reflective learning in terms of aspects relevant to technology design and contributes a discussion of the role of technologies and data in reflection.

The Role of Data in Technologies for Reflection
One starting point for research was the idea that data could play a central role in such technologies by representing a complementary viewpoint to learners’ memory of work practice. A second starting point was the idea that technology should guide and instruct users in reflection; and that guidance should adapt depending on what is reflected on and on how the user is already reflecting. In this endeavour, data plays two quite distinct roles: Firstly, data can represent relevant aspects of the object of learning, including about the learning activity itself as a support for the metacognitive process of monitoring and measuring own learning. Secondly, data can feed into adaptive, intelligent technologies that aim to remind, trigger, and guide (reflective) learning. These two functions can be differentiated by calling the first case “technologies for data-driven reflection” in which data represent relevant aspects of the object of learning or learning activity, and the second case “adaptive technologies for
reflection”. Naturally, the two may overlap in a single technical prototype and use case. Both data as basis for reflective learning, and adaptive technologies for reflection have been researched mostly in educational and private life settings. The present habilitation contributes empirical evidence that data-driven reflection can be designed meaningfully in workplaces. While data alone, without further instructional support can also work, complementary support in the form of additional coaching or adaptive technologies that structure reflection (adaptive reflection guidance) has also been studied and shown to be successful.
3 Related Work and Own Contribution

Chapter Summary
This chapter positions the present research in the field, identifies gap in research outside this habilitation, and lays out how this habilitation fills these gaps. This chapter’s core statements are the following:

- This habilitation is situated in the fields of technology-enhanced learning and human-computer interaction (Section 3.1)
- The goal of the present research has been to address informal workplace learning as relevant part of knowledge work. This issue has been addressed via creating and testing novel and innovative socio-technological artefacts in as realistic settings as possible, i.e. in field studies. In doing so, reflection theory, and in particular research on designing for reflection has been used and contributed to (Section 3.1).
- Research synthesised in this habilitation has previously been published in 26 peer-reviewed publications. Of these, six are journal articles, eight are conference papers, and the rest are demo, poster, works-in-progress and workshop papers. (Section 3.1).
- Existing design-oriented theoretical works on reflection besides this habilitation discuss phases in reflection, levels of reflection, and conditions conducive to reflection. This habilitation complements such work by contributing a concise terminology, patterns of iterations of reflection in the workplace, and a discussion of the roles of technology and data in reflection (Section 3.2).
- Data-driven reflective learning is, in related work, mostly explored in educational and private life settings. This habilitation contributes two prototypes for data-driven reflection (KnowSelf and MoodMap App). They instantiate two different types of data collection, namely automatic and manual tracking. Field studies in workplaces have shown these prototypes to support reflective learning, and give insights on specific challenges related to data-driven technologies for reflection in the workplace (Section 3.3).
- Adaptive reflection guidance technology has been explored in related work again mostly in educational settings. This habilitation contributes a concept for adaptive reflection guidance technology, and its instantiation in three prototypes (KnowSelf, MoodMap App, Medical Quiz). Field studies in workplaces have shown this concept to support reflective learning, and give insights on specific challenges for the design of adaptive reflection guidance technology in the workplace (Section 3.4).
3.1 Positioning in the Field: Design Science Research in Technology-Enhanced Learning and Human-Computer Interaction

Technology Enhanced Learning and Human-Computer Interaction
The present work is situated in the intersection of the research fields of technology-enhanced learning (TEL) and human-computer interaction (HCI). The research field of technology-enhanced learning explores the design and usage of technologies as tools that influence how learning happens from the perspective of learning science and that of technical (typically: computer science) research. In technology-enhanced learning, research therefore creates knowledge about i) how technologies shape learning activities, and ii) how to design technologies such that they shape learning in some desirable way. This is understood to be a sub-field of human-computer interaction (HCI) research in the sense that HCI research creates knowledge about i) how humans interact with computers and mediate their activities with computers; and ii) how to design computer technology such that the overall activities are impacted in a desirable manner.

Design Science Research
The overarching research approach taken in own work is design science research, most directly in the sense of Hevner et al. (2004) and Hevner (2007). This means in brief that i) the goal of the present research has been to address informal workplace learning as relevant part of knowledge work, ii) via creating and testing data-driven and adaptive technologies for reflection as novel and innovative socio-technological artefacts in as realistic settings as possible, i.e. in field studies in workplaces, and iii) using reflection theory, and in particular design-oriented research on designing for reflection as theoretical background; and in turn contributing to the body of such design-oriented literature.
These three aspects of own research correspond to three key aspects in design science research of relevance, design, and rigour (Hevner, 2007). By relevance, it is understood that researchers address an issue of practical relevance. Research needs to elaborate on this relevance in the case that is worked on, and for the environment in which an intervention will take place. Research needs to identify problems and pain points, and identify opportunities for design science research. By rigour, it is understood, that researchers draw on existing scientific bodies of knowledge in order both to understand the problem space, and to identify helpful design solutions as well as correct methods to test solutions. Research activities that ascertain and concretise the relevance of the issue, and research activities that draw on and contribute to theory cycles inform design activities in which artefacts are created. The designed artefacts intend to change some aspects of the environment in which they shall be placed, i.e., they serve as intervention. Design artefacts are evaluated in the field, within their environment of
intended use and usefulness. Insights from design and evaluation contribute to theory building overall design-oriented knowledge in the research field, thereby informing activities related to the aspect of rigour. Artefacts can be technology-based artefacts such as technical functionalities or interfaces, organisation-based artefacts, such as organisational structures and divisions of labour, or people-based artefacts, such as necessary trainings or specific patterns of usage (Hevner et al., 2004, paraphrased very closely from p. 84). Hevner et al.'s work is situated in a different, although neighbouring research field (information systems research) than the two in which this habilitation is positioned (TEL and HCI). I have however found the description by Hevner et al. most concise and useful.

Of course, Hevner et al.'s concepts can also be related to concepts proposed directly within human-computer interaction research, e.g., by Zimmerman et al. (2007), or learning sciences research, e.g., by Collins et al. (2004).

Zimmerman et al. (2007) argue, completely in line with Hevner et al., that one key characteristic of research through design is that it addresses a current given situation of the real world. Zimmerman et al. (ibid) highlight as one particular challenge to not only understand the current situation, but to also develop an understanding of what would be a more desirable state of affairs and what would therefore be success criteria. Finally, both Hevner et al. and Zimmerman et al. stress that in order for design-oriented activities to count as research, there must be some significant novelty in what has been designed; in addition of course to relevance, and to methodological soundness in generating insights from design. Similarly, Collins et al. (2004) emphasize design research as "refining practice" (ibid, p.19) and as in parallel contributing generalizable knowledge about the design of learning interventions (the authors in principle talk about instructional, not technological designs as interventions).

In own research, this approach and inter-connected way of understanding concrete workplaces as target environments for interventions, developing interventions, and using and developing theory, was consistently and iteratively applied. Initial user studies for instance confirmed that our target users do indeed understand continuous learning as "part of the job" (Pammer, Fessl et al., 2011 OWN). In parallel, foundational works on reflection, such as in particular Boud et al. (1985) and Schön (1983) provided the background on which to start designing artefacts and developing own theoretical contributions. In time, more mature and diverse contributions both to design-oriented literature on designing for reflection (elaborated in Chapter 4), and contributions in the form of experiences with and evaluations interventions based on technologies that were designed to support reflection in the workplace were created (elaborated in Chapter 5). Both kinds of contributions have been developed in close interaction to each other. The developed interventions are also novel and innovative, as data-driven and adaptive technologies for reflection and learning are, beyond this habilitation, to an overwhelming degree researched in educational or private life settings rather than in the workplace. Very naturally, the designed
interventions therefore are different than previously published interventions (gap in prior research as filled by this habilitation elaborated further below in this Chapter 3).

**List of Peer-Reviewed Papers**

The papers on which this habilitation is based are listed in Table 1 using a short reference notation. In the below list, papers are categorised according to the main type of contribution (theoretical/conceptual; design/empirical) and main research field (technology-enhanced learning; human-computer interaction). Naturally, most papers contain elements of all categories; wherever possible the categorisation below focuses on the main type of contribution and research field. In a few cases, a dual categorisation was made for the research field. All publications are peer-reviewed except for two that have been added for completeness (a book chapter - number 2; and a technical report - number 28). The peer-reviewed publications are six journal articles (J), eight conference papers (P), and the other 12 are demo, poster, works-in-progress, and workshop papers (WiP).

Papers are also listed, there being fully referenced and commented, in Appendix A.1 with respect to type of paper (Journal, conference paper, work-in-progress-paper, book or technical report); and own contribution.

Table 1: Overview of own publications contributing to this habilitation.

<table>
<thead>
<tr>
<th>Short paper reference (identifying authors, year, title, short name of venue)</th>
<th>Main type of contribution</th>
<th>Main research field</th>
</tr>
</thead>
<tbody>
<tr>
<td>(B) Fessl, Wesiak &amp; Pammer-Schindler, 2018 - Transfer of Theoretical Knowledge into Work Practice: A Reflective Quiz for Stroke Nurses. Knowledge Management in Digital Change (Book).</td>
<td>Design / Empirical</td>
<td>TEL</td>
</tr>
<tr>
<td>(J) Fessl, Wesiak et al., 2017 - In-app Reflection Guidance: Lessons Learned</td>
<td>Design / Empirical</td>
<td>TEL, HCI</td>
</tr>
<tr>
<td></td>
<td>Title</td>
<td>Authors, Year</td>
</tr>
<tr>
<td>----</td>
<td>----------------------------------------------------------------------</td>
<td>---------------</td>
</tr>
<tr>
<td>9</td>
<td>A Reflective Quiz in a Professional Qualification Program for Stroke Nurses: A Field Trial.</td>
<td>(WiP) Fessl et al., 2016</td>
</tr>
<tr>
<td>11</td>
<td>In-App Reflection Guidance for Workplace Learning.</td>
<td>(P) Fessl et al., 2015</td>
</tr>
<tr>
<td>12</td>
<td>The Value of Self-Tracking and the Added Value of Coaching in the Case of Improving Time Management.</td>
<td>(P) Pammer et al., 2015</td>
</tr>
<tr>
<td>16</td>
<td>Understanding and Supporting Reflective Learning Processes in the Workplace: The CSRL Model.</td>
<td>(P) KroGSTIE et al., 2013</td>
</tr>
<tr>
<td>17</td>
<td>Fostering Collaborative Redesign of Work Practice: Challenges for Tools Supporting Reflection at Work.</td>
<td>(P) Prilla et al., 2013</td>
</tr>
<tr>
<td>18</td>
<td>Surprise, Surprise: Activity Log Based Time Analytics</td>
<td>(WiP) Pammer &amp; Bratic, 2013</td>
</tr>
</tbody>
</table>
3.2 Theoretical Considerations on Designing for Reflection - Related Work and Own Contribution

The present habilitation draws on foundational works on reflection like Boud et al. (1985) or Schön (1983). More concretely, however, it contributes to and complements a body of literature that develops an understanding of reflection that is translatable and relevant to designing for reflection. In this section I lay out such works.
**Phases in Reflection**

A perspective of understanding what are different phases in reflection, or different types of action within reflection, lends itself to supporting designing for reflection as it enables thinking in a more fine-granular manner about the different roles that technologies can play in reflection.

Baumer (2015) has proposed three principal dimensions along which reflection should be understood by designers, namely breakdown, inquiry, and transformation, based on a literature survey. By breakdown, Baumer understands situations or moments that constitute the starting points for reflection. Breakdowns include elements of surprise, puzzlement, conflicts or “explicit consideration of that which was previously unconscious and implicit” (ibid, p.6). Inquiry means the process of “generating, testing, revising, and further testing hypotheses” (ibid, p.6), a “re-examination of things - concepts, ideas, theories” (ibid, p.6). Transformation is a change in understanding, conceptual schemata, values, or decisions in the sense that “reflective decision making (...) enables decision making that is not subject to (...) biases” (ibid, p.7). Technology can support transformation by enabling users to change their perspectives and find ways to apply results from inquiry.

Li et al. (2010) investigate personal informatics, a field of research related to the notion of self-tracking, often also called “quantified self”. The core idea of the quantified self is measuring relevant elements of oneself and one's behaviour with the goal to improve on it. Such self-monitoring with the purpose of creating awareness and (eventually) self-improvement can be understood as reflective learning, where the goal is to learn about oneself and own behaviour and to change oneself and own behaviour (e.g., weight/food intake). The authors identify five stages for self-tracking based on 68 surveys and 11 follow-up interviews of quantified-selfers: In a preparation stage, people decide to start self-tracking, and prepare their own method (tools, procedure) to do so. In the collection stage, people are engaged in collecting data, either manually via calendar entries for instance, or automatically such as when analysing phone usage. In an integration stage, people “prepare, combine and transform (data)” (ibid, p.5). In the reflection stage, people reflect on data; and in the action stage, users “choose what they are going to do with their newfound understanding of themselves” (ibid, p.6). In this context, the role of technology is essentially to support the collection, analysis, visualization and interaction with relevant data.

Own theoretical work builds on the understanding that reflection consists of different phases at a similar level of granularity than Baumer (2015), but building more fundamentally on Boud (1985). Own theoretical work contributes the understanding that reflection is cyclic in workplaces. As one salient specificity of workplace learning, it has been identified that in subsequent cycles of reflection may have different reflection participants (cp. Section 4.2).
Levels of Reflection
Fleck & Fitzpatrick (2010) structure their discussion around levels of reflection. Levels of reflection can be understood as the extent to which an activity, or an outcome of an activity, actually is reflective. The model is based on literature about reflection, and informed by design studies on technology-supported reflective practice of teachers. Level zero, revisiting, consists of reporting the past, without adding significant "reflective thought". This level is not understood as reflective, or would not count as reflection in the authors' understanding (hence numbered zero). Level one, reflective description, includes justification or reasons for action or interpretation" (ibid, p.3). In level two, dialogic reflection, "relationships between pieces of experience or knowledge" (ibid, p.3) and generalizable insights are sought. In level three, transformative reflection, "fundamental questions" are asked, and change of future practice is explicitly intended. In level four, critical reflection, "social and ethical issues are taken into consideration" (ibid, p.3). The authors use the four levels to discuss what role technology could play in achieving a certain level of reflection, namely to support revisiting, prompt users for explanations (asking reflective questions) or providing alternative perspectives. Fleck & Fitzpatrick’s levels of reflection have, in empirical work as described in Chapter 5, been used to support qualitative analysis of free-text notes that participants made in tools.

Conditions for Learning by Reflection
Slovák et al. (2017) revisit the idea of reflective learning in the context of social-emotional learning. They develop their concept of reflective practicum, which is based on Schön (1983)'s work. The concept is illustrated by two case studies on social-emotional learning, one in professional learning, and one in primary education. Key to a reflective practicum is that learners are enabled to construct knowledge by themselves in a setting that provides learners with the experiences that are "real-enough" to learn from. The authors highlight that technology design needs to design for realistic but safe engagement with learning experience by structuring tasks to "generate particular experiences" (ibid, p.9), to provide access to real-world experiences made by others, and to "scaffold the reflection process" (ibid, p.9). In contrast to the reflection approaches described above, reflective practicum includes the design (specification) of the experiences to be reflected on such that they are most likely to induce reflection. Such design is not easily applicable to every day work and life, in which people reflect upon situations they encounter, outside an instructionally designed and designable environment. However, it is useful, also in designing for informal workplace learning, to think of ways to make the workplace learning more suitable for learning. In own research, this is not apparent in descriptions of results, but all social aspects of socio-technical interventions have been designed in the sense of negotiating with (representatives of) target users how technologies could meaningfully be used embedded into in daily work practice. Safe engagement of learning experience in workplace learning for instance consists of ascertaining which
data, if any, could be shared with whom (cp. the discussion on balancing privacy and usefulness of intervention in the case of self-tracked mood data in Section 6.2 on p. 68).

**Contribution of Own Work**

To summarize, outside this habilitation, design-oriented theoretical works on reflection exist that discuss elements of reflection, levels of reflection, and conditions conducive to reflection. Two of those works (Baumer, 2015; Slovák et al., 2017) have been published only whilst this habilitation has been ongoing, which highlights the timeliness and novelty of own work, and none of those have been developed in the context of workplace learning.

Own work complements the above literature by laying out a complementary perspective on **roles of technology and in particular of data** (Krogstie et al., 2012; Pammer et al., 2017), by **developing a concise terminology that supports design in workplace setting** by explicitly taking into account the social context of organisations (most notably: Krogstie et al., 2013; Pammer et al., 2017), and by having identified **patterns of iterations of reflection** that seem specific to workplaces (most notably: Prilla et al., 2012\textsuperscript{OWN}; Prilla et al., 2013\textsuperscript{OWN}; Pammer, 2015\textsuperscript{OWN}; Pammer et al., 2017\textsuperscript{OWN}).

### 3.3 Technologies for Data-Driven Reflective Learning – Related Work and Own Contribution

Research on data-driven technologies for reflective learning investigates applications that help people to digitally track an aspect of their lives that is important to them.

In own work, I have investigated **data that represents relevant aspects of work practice**. In related fields, such as quantified self or learning analytics, data represents relevant aspects of learning activities (e.g., Siemens, 2013), or of activities in private life (e.g., Choe et al., 2014). Own work thereby complements these fields fundamentally by investigating data about a different “kind of thing”. From this perspective, while own work therefore investigates data-driven reflective learning about work, quantified self investigates data-driven reflective learning about aspects of private life (and actually focuses a lot on the subsequently aimed-for behaviour change), and learning analytics investigates data-driven reflection about learning (for a variety of stakeholders). Seen the other way around, data-driven technologies for reflection in the workplace then could be called “analytics of work practice that support learning”; with reflection guidance as one particular functionality that aids learning on top of analytics.

Overall, these fields share concerns on collecting relevant data, processing data (analytics), and directing results into social systems such that they induce learning, and overall create an impact. Firstly, collecting relevant data is not easy in cases where target users either use a plethora of digital tools, or carry out relevant parts of their activities in a non-digital manner – all of which is true in private life, in work life, and in educational settings (cp. Pardo & Delgado Kloos, 2011 for learning analytics in educational settings; Kay &
Kummerfield, 2011 for lifelong learner modelling in the sense of capturing relevant data about a plethora of activities including private and work-related for the purpose of learning; and Ruiz-calleja et al., 2019 for workplace learning analytics). Secondly, processing data to uncover non-obvious patterns in data (data analytics) is an active and huge field of research as evidenced by two striving research communities around learning analytics and educational data mining. Thirdly, the ultimate goal of research is typically to present data, or data analytics results to a single person, or group of persons, in order to do something about that – in order to transform the reflection object. Baumer (2015) writes that “[achieving/supporting] transformation likely poses the most difficult challenge to designers”. Fundamentally, there are four target user groups of analytics, where for the first three, typically interactive systems for data representation and analysis are developed: These are learners (all use cases presented in this habilitation), teachers (e.g., in teacher-facing learning analytics, where teachers adapt how they respond to single students without changing their overall teaching style as described by the Purdue Signals study by Arnold, 2010) or a wider group of decision makers (e.g., in institutional learning analytics as discussed in Siemens, 2013; or in the push pattern of reflection as described above in Section 4.2).

Fourthly and in complement, analytics could be oriented to systems designers who change the socio-technical design of the system under scrutiny (cp. Baker, 2016; for a discussion of educational data mining as leading to foundations for novel technology-designs).

It is of course also along the same dimensions of data collection, analysis, presentation and means of creating impact, that these fields vary; such as in which data are collected, in what quantities comparable data can be collected (which impacts the types of analytics that are meaningful); which analytics are investigated; and which theories and approaches to directing analytics to impact are taken. Quantified self research for instance focuses on theories of behaviour change over learning; whereas learning analytics naturally leans more on learning theories, including reflective learning, experiential learning, or sensemaking (where analytics results serve as artefact in sensemaking).

The below discussion of related work focuses on works that deal with collecting data in environments unstructured for learning, i.e. in informal learning settings.

**Empirical Studies**

Choe et al. (2014) have explored 52 users who have intensively used self-tracking applications, recruited from Quantified Self Meet-Ups. As pitfalls in completely unguided data collection, the authors identified i) tracking too many things and ii) not tracking triggers and context. Li et al (2010) identified preparation, collection, integration, reflection and action as five stages for self-tracking based on 68 surveys and 11 follow-up interviews with people already engaging in quantified self practice. In a follow-up study (Li et al., 2011), the authors identified two distinct phases in which different categories are emphasized, namely “discovery”, in which users are trying to understand data
and set goals; and “maintenance” in which users have already set goals, and are trying to achieve them. The Reflection Companion (Kocielnik, Xiao et al., 2018) goes beyond the previously mentioned tools in stimulating reflection by not only collecting (in this case via the FitBit\(^3\) and visualising data, but also offering interactive reflective mini-dialogues, which were crafted by researchers together with future study participants in a user-centered design process.

**Example Tools**

Example tools for data-driven reflective learning are the Affective Diary (Ståhl et al., 2009) which estimates and visualizes users’ affective status, UbiFit Garden (Consolvo et al., 2009) which estimates and visualizes users’ physical activity with the goal to encourage more of it, or UbiGreen (Froehlich et al., 2009) which monitors users’ transportation habits with the goal to encourage green (in the sense of environmentally friendly) transportation habits.

In educational settings, data as basis for learning has been explored under the names of open learner modeling (e.g., Kay & Kummerfield, 2011) or learning analytics/learner dashboards (e.g., Schwendimann et al., 2017). In learning analytics, indeed, teachers are amongst the core target user groups of analytics next to students (cp. Schwendimann et al., 2017); however, the data typically represents activities and achievements of the students, not of teachers; and teachers use data as basis for decision-making in the sense of deciding on personalized interventions or adapting teaching design (as e.g., described in Xhakaj et al., 2017) to the present student cohort as compared to using data to gain insights on and systematically change own (teaching) behaviour, although that might be a side-effect.

**Data-Driven Reflective Learning in Workplace Settings**

Significantly less research, beyond work that is part of this habilitation, has been carried out on data-driven technologies for learning in workplace settings. The following two contributions stand out: Müller et al. (2015) deployed badges that measure physical nearness between carers and residents in a care home setting. Nearness between carers and residents was measured. Carers used this data to reflect on “the time shares allocated to each resident” (ibid). One of the authors’ conclusions which seems particularly relevant in light of own empirical work was that it was sometimes difficult to move from understanding work patterns to changing them, for instance due to limited available time and personnel. Kocielnik, Avrahami et al. (2018) developed two interactive, dialogic agents that engaged users in manually journaling their time use at work and reflecting on it. The two agents both were based on the same dialogic intelligence, but had two different interfaces where one was text-based and the other was voice-based. This paper is especially relevant for the present work as it also touches on time-management, even though learning about and improving time management was not the explicit goal of the authors, who framed their research more in

\(^3\) https://www.fitbit.com
reflection on goals, goal setting, and achievements. Nonetheless, this study is still set in the workplace, and describes a technology-based reflective intervention throughout some time, and it indicates that such an intervention was found to increase awareness about own time use. The study uses only manually created data however, so it cannot make a statement about the usefulness of automatic activity log data for learning about time management. As highly interesting insight in relationship to our own work, we see the authors' discussion about the balance between general and specific (to specific journal entries) reflection questions. The authors note that questions that were too general were found to be hard to think about, and questions that were too specific are susceptible to pointing to irrelevant data. This constitutes the technical perspective on the dichotomy of generic and directed prompts as discussed below in Section 3.4.

**Contribution of Own Work**

Within this habilitation, exemplary socio-technical interventions for data-driven reflection in the workplace have been created. They have been tested and evaluated in multiple field studies in workplace settings in terms of usage, generated insights by learners based on data, and subsequent impact on individual behaviour the organisation (most notably: Fessl et al., 2017 OWN; Rivera-Pelayo et al., 2017 OWN; Pammer et al., 2015 OWN). These provide evidence for successful implementation of the principle of using data, both automatically and manually tracked, as basis for reflective learning in the workplace; and for the viability of adaptive reflection guidance technology. In addition, the field studies served to derive design-oriented insights.

### 3.4 Adaptive Reflection Guidance – Related Work and Own Contribution

Beyond supporting the collection and analysis of relevant data as basis for reflection, as discussed above under the header of “technologies for data-driven reflection”, technologies can also be used to guide reflection. In this section, specifically technologies that adapt the given guidance to some contextual characteristic are reviewed. For instance, diaries, journals and e-portfolios can be implemented electronically, and pre-structure the reflective activities of users/learners. However, unless they are implemented in an adaptive manner, they are not discussed below.

Adaptive reflection guidance technologies often prompt users to reflect by providing a question such as “What have you accomplished today?” (cp. Kocielnik et al., 2018), sentence starters such as “To approach the solution to the problem step by step I have to …” (cp. Ifenthaler, 2012), direct instructions, or pictures and graphs that incite reflection (cp. Ifenthaler, 2012, p. 40). The goal of prompts is to focus user attention on relevant aspects or experiences of their learning and working activities.

Adaptive reflection guidance is often also published under the term “reflection prompts” or “reflection amplifiers” (Verpoorten et al., 2011). In the present
work the term “adaptive reflection guidance” or “adaptive reflection intervention” is introduced as overarching term, as it highlights the goal (to guide reflection) or the intervention to a particular use case setting, as well as the technological complexity (adaptivity). The term prompt is used below to denote a single instance of an intervention by the overall adaptive reflection guidance technology. Prompts can be proactive, i.e. grab the user’s attention proactively by popping up, or becoming visible following some internal rule set either by designers or users at a time distinct to usage time. Prompts can also be visual cues, or information that is otherwise accessible, to users within their learning or working environment.

Benefit for Learning
In learning management systems in a formal education context, prompts emerged to be a viable and appropriate approach for guiding and initiating reflective learning (Davis & Linn, 2000; Ifenthaler, 2012). Here, prompts are used to organise, retrieve, monitor or evaluate knowledge and to reflect on learning progress (Bannert & Reimann, 2012; Ifenthaler, 2012; Xun & Land, 2004). Davis (2003) differentiates between generic and directed prompts. Generic prompts “ask learners to stop and reflect about their current problem solving activities” (Ifenthaler, 2012, p38). Directed prompts on the other hand encode expert knowledge on general as well as domain-specific ways to reflect and solve problems. Ifenthaler (2012) studied both generic and directed prompts in an experimental setting with university students. The author found generic prompts to give learners some guidance whilst also giving learners significant autonomy in choosing problem solving strategies. In contrast, directed prompts give more step-by-step instructions and restrict autonomous work. Kirschner et al. (2006) consider generic prompts “minimal guidance” and need to be expected to be of less benefit to learners who are not already sufficiently well-versed in the learning domain. Using terminology of Ifenthaler (2012), such users are not be able to make use of the available freedom of action (autonomy).

Context-Awareness: Timing and Concretisation
One core challenge in designing adaptive reflection guidance is the right timing of every single prompt in the sense of not interrupting a user where (s)he should not be interrupted (Fischer et al., 1993). Thillmann et al. (2009) showed that the timing of a prompt affects the learning outcome. Timing the prompt rightly is both a conceptual challenge at design time, and a technical challenge (accuracy). By the latter, I mean that when prompts are designed to adapt their timing based on user activity, user activity needs to be captured and automatically interpreted adequately. This is also known to be challenging from the field of ubiquitous computing and human-computer interaction, where there have been more general attempts to develop context-aware proactive prompting that doesn’t disrupt users. Ho & Intille (2005) presented prompts directly after the completion of identifiable actions, while Pejovic & Musolesi
identify generally opportune moments for interruption. Synthesizing, timing any kind of proactive prompts from computers to humans well is an open challenge for research.

From an instructional design perspective, directed prompts are more suited to non-experts in a learning domain. As much learning support is designed for non-experts, even in professional learning, it is important in many systems to be able to provide such directed prompts. As an example for directed reflection guidance, Broos et al. (2017) visually represent information about relevant others (typically: peers or experts) in relationship to data about the user, such as showing the student how many others in his/her cohort have similar scores. Kocielnik, Avrahami et al. (2018) have designed prompts that explicitly refer to earlier information given by users as described e.g., by Kocielnik, Avrahami et al. (2018). Neither of these works, however, is adaptive in the sense of automatically identifying which pieces of data or materials in systems are particularly interesting to reflect on; and they are far from adaptively giving guidance on how to approach reflecting on such salient pieces of data or materials.

Coming from the side of designing technologies in support of work, McCall et al. (1990) and Fischer et al. (1993) have developed knowledge based systems called “critics” by the authors, which roughly correspond to what is called adaptive reflection guidance in this work. A critic is a computer functionality that “point[s] out problematic situations”, and optionally “advise[s] users on how to improve the product and explain their reasoning” (Fischer et al., 1993; p. 287). Concretely, the authors have developed a critiquing system that is embedded into a system for designing kitchen floor plans. The system is based on an explicit knowledge base that contains mandatory design rules and recommended good design practices. Where such rules/practices are violated, the critic presents an argument that critiques the design. Where no rules are violated, the critic asks general questions about the design that are intended to induce reflection. The system thereby contains both directed and generic prompts. The authors’ works stand out in literature as they are primarily situated within workplace learning, and are able to generate both directed and generic prompts due to the underlying knowledge base consisting of rules. The discussed prototype thereby constitutes, for designing a kitchen floor plan, an extremely early implementation of a vision that is, for wider use cases, still not realised. The authors’ solution approach is based on an explicit knowledge base. Creating such a knowledge base is challenging because adaptive directed prompts need to have expert knowledge about the learning domain, as well as about learning (=how to reflect). Such knowledge is in many settings ill-structured, complex, and evolving. Consequently, the overall challenge is to capture a human (teacher)’s knowledge within an intelligent (tutoring) system, without making the effort to model that knowledge higher than the benefit derived from having the resulting system. While modelling effort may be significantly lower (or feasible at all) when compared with expert systems who could automate the task itself (i.e. kitchen design in...
Fischer et al., 1993; - see the discussion on modelling effort on p. 287), modelling effort is still significant.
Overall, a realisation of directed prompts as context-aware pieces of software that adaptively suggest what concretely to reflect on, and how, is therefore a second core research challenge for designing adaptive reflection guidance.

**Contribution of Own Work**
As part of this habilitation, a concept for adaptive reflection guidance technology that is grounded in reflection and human-computer interaction theory has been developed. The concept implements mostly generic reflection prompts. The concept has been instantiated in three different applications that support workplace reflection, and has been evaluated in four multi-week field trials in workplaces (partly within the same field studies in which technologies for data-driven reflective learning was investigated). This habilitation can therefore offer insights on the viability as well as challenges for design of adaptive reflection guidance technology in workplace environments (most notably: Fessl, Wesiak et al., 2017\textsuperscript{OWN}).
Note that at the time this research stream was carried out, reflection guidance technology in workplaces was not published at all outside domain-specific systems (cp. the literature review in Fessl, Wesiak et al., 2017\textsuperscript{OWN}, and Fessl, Blunk et al., 2017\textsuperscript{OWN}). By now, as noted above, Kocielnik, Avrahami et al (2018) have also published on reflection guidance in a workplace setting.
4 Design-Theoretical Considerations

Chapter Summary:
This chapter lays out theoretical considerations for designing for reflection. The following are this chapter’s core statements:

• All contributions in this chapter are informed by background literature and own empirical and design work. In turn, such design-theoretical contributions influenced own empirical and design work.

• The following terms were elaborated and contributed to literature, together with colleagues: reflection session, reflection participants, reflection trigger, reflection scope (who should learn), who learns, and reflection outcome, reflection cycle. Reflection object is a new concept that is currently under work, and is already in use in this habilitation (Section 4.1).

• The following patterns of iterative reflection (subsequent reflection cycles) were identified in empirical work: Pull – reflection participants are added to a subsequent cycle in order to gain additional input and advice; Push – reflection participants are added to a subsequent cycle in order to gain support for implementing reflection outcomes; and knowledge sharing – reflection participants are added to a subsequent cycle in order to share knowledge (Section 4.2).

• Data can play two roles in reflection. Firstly, the role can be to represent relevant aspects of the reflection object, including the reflection activity (data-driven reflection). Secondly, the role can be to feed into adaptive technologies for reflection, of which in particular adaptive reflection guidance has been investigated in the present work (Section 4.3).

• Social software functionality in general; and in particular sharing data and materials (manually created artefacts), or integrating data and materials from multiple people is the technological support for patterns of subsequent reflection cycles (Section 4.3).
This chapter lays out theoretical work done as part of my habilitation, i.e. research activities in which the goal was to **elaborate a theoretical basis for designing socio-technical interventions for reflective learning in the workplace.**

As core contribution to the fields of technology-enhanced learning and human-computer interaction, work presented in this chapter provides a **design-oriented terminology for reflective learning** including a cyclic model for computer-mediated learning in the workplace that we found useful and necessary in order to communicate in interdisciplinary teams when designing for reflection in the workplace. In addition, we have identified **patterns of iterations of reflection** that seem specific to workplaces; and have discussed potential **roles of technology and in particular roles of data** in reflection.

In line with the overall design science research approach, theoretical work informs as well as is informed by empirical work.

### 4.1 A Terminology and Cyclic Model for Reflective Learning

Interdisciplinary discussions in the course of our work made apparent that different communities and different publications mean different things when referring to reflection or reflective learning. In particular, we found consistent confusions around understanding reflection to be a cognitive or a social activity, and around finer points of understanding what is individual, collaborative, or organisational reflection.

Such discussions led us to develop a terminology that enables very precise phrasings in talking about reflection (Pammer, Knipfer et al., 2011\textsuperscript{OWN}; Krogstie et al., 2013\textsuperscript{OWN}; Pammer et al., 2017\textsuperscript{OWN}). The terminology has been developed based on literature, and in parallel to own and colleagues’ empirical work in order to facilitate interdisciplinary communication on a shared research theme, namely designing for reflection in the workplace.

The following are key terms that we brought into literature:

- **Reflection participants** – these are the actors who reflect.
- **Individual and collaborative reflection processes**: The number of reflection participants defines whether we talk about an individual (one reflection participant) or collaborative (multiple reflection participants) reflection process.
- **Cognitive process, observable individual activities, social process** – By reflection one can mean a cognitive process, observable individual activities, and more complex social processes. Individual activities and social processes scaffold as well as indicate the cognitive process. Both individual and collaborative reflection processes have cognitive and social processes as constituent elements.
- **Reflection trigger** – something that starts the reflection trigger. We prepared the concept to encompass both internal, psychological
triggers like a cognitive dissonance; as well as external impulses that can invite, motivate or simply call for reflection. The reflection trigger as starting point is something unique that we provide as term to literature. In our understanding, the trigger also kicks off the point in time where the subsequent reflection session is prepared. This is an action or a chain of actions that is outside the operative work process, but equally outside the reflection session.

- **Reflection session** – a time and space in which reflection takes place; with a concrete objective and concrete reflection participants.
- **Reflection objective** – something that shall be achieved and/or resolved.
- **Reflection content** – concrete experiences and data that are reflected on with the goal to achieve/resolve the reflection objective.
- **Reflection object** – the overarching entity which is reflected on; sometimes called “topic of reflection”, and which is represented partially by the reflection content. This is an additional concept in comparison to own published work, i.e. this is a concept-in-progress, and is discussed briefly also in the discussion in Section 6.1.
- **Reflection scope** – the social entity who should learn, i.e. the individual reflection participant(s), a group of people, or a formal social entity (i.e., the organisation).
- **Who learns** – the social entity who actually learns; named individual, collaborative or organisational learning respectively.
- **Reflection outcome** – knowledge, perception, attitudes, behaviour (and analogous concepts for collaborative and organisational learning) that is adapted or created through reflection.
- **Reflection cycle** – a sequence of steps starting with the decision to reflect, and ending with the decision to move back to action; or the decision to initiate a different reflection cycle which may have a different objective, different participants, a different time or place, etc (Krogstie et al., 2013\textsuperscript{OWN}, Pammer et al., 2017\textsuperscript{OWN}).

4.2 Patterns of Iterations of Reflection Cycles

Using the above described terminology allowed us to differentiate between those who reflect, and the scope of reflection. Adding the cyclic representation of reflection, and based on field observations and interviews, we first identified two directions of communication – which we called **push and pull** – in terms of who invites whom to a subsequent reflection session (Prilla et al., 2012\textsuperscript{OWN}). In the push case, reflection participants start by reflecting on own experiences, and within their own scope. As soon as they identify that there are issues that are outside their competence and power within the organisation, they push the reflection outcomes to future reflection participants who have this competence and power. In the pull case, reflection participants start by reflecting on an organisational scope, and identify that input is needed from future reflection participants who are closer to
operations, i.e. who will be able to reflect on the selected objective based on own experiences. These two directions of communication have been useful for instance to conceptualize the potential of collaborative mood tracking in relation to public spaces, to support open and reflective public discourse on public spaces, and communication between users of public spaces and those responsible for public spaces (Pammer, 2015\textsuperscript{OWN}). Secondly, framing iterating between reflection cycles with different reflection participants together with the push/pull direction of communication allowed us to identify a barrier for organisational learning through reflection, i.e. lost learning opportunities: If communicating reflection outcomes from one reflection cycle further seems to require too much effort to reflection participants, then they may decide to keep their thoughts for themselves. The learning opportunity is then lost for someone else besides the present reflection participants; a disadvantage for the overall organisation.

In a parallel analysis, colleagues and I focused on identifying rationales for choosing or inviting reflection participants for follow-up reflection cycles (Prilla et al., 2013\textsuperscript{OWN}).

Synthesizing work on communication directions and rationales for choosing/inviting reflection participants, three more general patterns of subsequent reflection cycles have been identified (unpublished extension of above prior work): Pull – inviting additional reflection participants in to reflection in order to gain additional input and advice; push – inviting additional reflection participants in to reflection in order to gain support for implementing reflection outcomes; and knowledge sharing – inviting additional participants in to reflection in order to share knowledge, and to teach. The pull and the knowledge sharing pattern here serve to “draw from and contribute to collective knowledge” (Littlejohn et al., 2012; p. 229) respectively; while the push pattern serves to direct reflection into action. Such empirically informed theoretical insights highlight the connection between individual learning in the workplace to learning in informal groups in organisations, as well as to more formal organisational learning.

4.3 The Role of Technologies and Data in Reflection

Looking towards designing for reflection, a very broad question that colleagues and I asked was: What are possible roles of technologies in reflective learning? We answered this by starting from the basic model as described above, and based on prior literature, own empirical work on understanding reflection in the workplace, and of course own background knowledge of technologies. In (Krogstie et al., 2012\textsuperscript{OWN}), we identified the overall potential roles of technologies for reflection as capturing and providing data relevant for reflection, reminding people to reflect, supporting collaborative activities related to reflection such as sharing and discussing experiences, actively structuring or guiding reflection, or providing means to document the reflection process itself as possible roles of technology.

More specifically, the role of data is one of the focal points of the present habilitation. In principle, data plays two significantly different roles in reflection:
Firstly, data can represent relevant aspects of the reflection object, including the reflection activity. Technologies in which such a representation plays a key role are called \textit{(technologies for) data-driven reflection}. The role of data as representation of the reflection object is elaborated on in more depth right below. Secondly, data can feed into \textit{adaptive technologies for reflection}. With respect to this, I have focused on adaptive reflection guidance, i.e. adaptive technologies that trigger and structure reflection; and expand on this concept in Section 5.5.

\textbf{The Role of Data to Represent the Reflection Object}

A key theme in the present habilitation is the role of data in reflection as representation of relevant aspects of the object of reflection. The object of reflection is the overarching entity, topic, or theme that is reflected on. Time management, or medical knowledge about strokes are two examples from own work. Any data or materials contained within a single software tool (reflection tool content) is of course only ever a partial representation of a reflection object.

In this section I elaborate on the role of data and materials to represent the reflection object. The description below is based on what has been previously published but naturally presents an updated understanding.

\textit{Data and Materials}

In own work, I have mostly investigated \textit{data that represents relevant aspects of a work-related reflection object}, such as time management, own mood in relation to incoming customer calls, or new knowledge in a quiz as it relates to past and future work practice.

In addition, entities that were called “materials” in Pammer et al. (2017\textsuperscript{OWN}) repeatedly turned up: By data we originally understood data created by machines. However, in empirical work, also mood entries were understood data, albeit manually tracked data. This understanding was based on the rationale that single mood entries constitute very specific and fine-granular statements. These need contextualization, made explicit by digitally provided information or in offline face-2-face discussions, in order to constitute meaningful information for reflection. In extension to Pammer et al. (2017\textsuperscript{OWN}), I therefore understand data more widely in the specific sense definition by Donald Kraft as given in (Zins, 2007) of “Data are atomic facts, basic elements of “truth,” without interpretation or greater context. It is related to things we sense.”

By materials, Pammer et al. (2017\textsuperscript{OWN}) understood “physical or digital artefacts that are created by humans both during the plan and do work stage and during the conduct reflection stage” (ibid). In extension to previous work, I understand materials now as any humanly created artefact that represents relevant aspects of the reflection object. This loosens the understanding to all relevant artefacts, no matter in which phase they have been generated. Materials typically contain more than raw data, namely information or knowledge. For information I follow again the definition by Donald Kraft as
given in (Zins, 2007), and understand it as “Information is a set of facts with processing capability added, such as context, relationships to other facts about the same or related objects, implying an increased usefulness. Information provides meaning to data”. Information may also be constituted by a set of data points and materials within a single reflection tool. By knowledge, finally, I loosely follow Michel Menou as cited in (Zins, 2007), who understands knowledge as “information that is understood, further to its utilization, stored, retrievable and reusable under appropriate circumstances or conditions” (ibid).

Synthesising across all own research, materials, because they are able to encode information and knowledge, need to be understood as a valuable and necessary complement to data in representing the reflection object in order to encode complex and knowledge-intensive aspects of work practice (see also the related discussion in Section 6.1).

The Function of Sharing Data and Materials in Reflection

Both data and materials can be about experiences from multiple reflection participants, as well as from others not participating in reflection. Such sharing of data, or inversely, integration of data, has the following functions in data-driven reflection (cp. Pammer, Prilla & Divitini, 2015OWN). Firstly, relevant multiple perspectives on the reflection object can be combined and integrated within a single tool. Secondly, sharing allows the communication of reflection outcomes including data that form the basis for insights and ideas for action. This function of sharing corresponds to the “push” pattern of subsequent reflection cycles, as it supports communication to reflection participants who can support the implementation of reflection outcomes. Thirdly, sharing can serve to communicate a change in knowledge, values, perception; thereby supporting the “knowledge sharing” pattern of subsequent reflection cycles.
Chapter Summary
This chapter summarizes research streams that had the goal to design, implement and evaluate socio-technical interventions for reflective learning that are based on data-driven and adaptive technologies. The following are this chapter’s core statements:

• All interventions consist of software prototypes and intended reflective practice (socio-technical interventions), and were evaluated in multiple-week field studies in real workplaces with professionals (knowledge workers) as study participants.

• Field studies assessed and confirmed the suitability of using data as basis for reflecting on and improving work practice (Sections 5.2 and 5.3).

• Activity log data surprises users by showing the fragmentation of their work activity (Section 5.2).

• Activity log data together with reflective practice led to reasonable insights about own time management, and to experimentation with strategies for improving time management in the case of IT and strategy consultants (Section 5.2).

• Collaborative mood tracking was shown to facilitate communication, and to trigger reflection on collaboration in a field study with a spatially distributed team of knowledge workers (Section 5.3).

• Collaborative mood tracking served as trigger for face-2-face peer and managerial support within b2b call center teams. In one such case, customer satisfaction, a KPI of the call center, was significantly higher at the end of the intervention than before (Section 5.3).

• Reflection guidance technology was conceived and instantiated in three apps (KnowSelf, MoodMap App, Medical Quiz). They support reflection-in-action through proactive prompts, or other cues that are accessible by self-directed action by users; reflection-on-action through reflection diaries, aggregate reports over data, and again through proactive prompts; and contextualisation of data (Section 5.1).

• Field studies show that adaptive reflection guidance technology engaged users in reflective learning (Section 5.1).
This chapter lays out design and empirical work done as part of my habilitation, i.e. research activities in which the goal was to design, develop and evaluate socio-technical interventions for reflective learning, based on data-driven and adaptive technologies.

The baseline assumptions, to be tested in concrete research streams, of the designed, refined, and evaluated socio-technical interventions were

1. Data representing relevant aspects of a learning topic can induce reflective learning in the workplace/in relation to work.
2. Adaptive reflection guidance technology can facilitate and engage users/learners in reflective learning in the workplace/in relation to work.

As core contribution to the fields of technology-enhanced learning and human-computer interaction, work presented in this chapter constitutes evidence that technologies for data-driven reflective learning as well as adaptive reflection guidance can work as expected also in workplace settings. Design implications and themes overarching the single research streams are discussed in the subsequent Chapter 6.

In line with the overall design science research approach, empirical work informs as well as is informed by theoretical work.

User-centered Design
Within the overall research framework of design science research, the technological artefacts were developed following a user-centered design process. This means, that researchers spent significant time in understanding current work and workplace learning practice as well as available technologies prior to design (as documented in Pammer, Fessl et al., 2011 Own). Ideas for concrete technological prototypes were informed by such empirically-generated understanding as well as by theory-based understanding. In each of the below outlined concrete research streams, ideas for technology artefacts matured from vague ideas, drawings on paper, paper prototypes, and visionary stories to click prototypes, semi-functional prototypes, and finally research prototypes that had the core functionality necessary to test the overall idea in a field study. In this process, ideas in every stage of maturity were cross-checked with target users or their representatives. The below described research prototypes (Section 5.1) and overall socio-technical interventions (Sections 5.2- 5.4) constitute of course very mature versions of the created technology artefacts. Finally, especially the social practice around technical prototypes in field studies were strongly co-designed with (representatives of) target users.

Such a process acknowledges that researchers in technology-enhanced learning and human computer interaction have background knowledge about these fields, users have background knowledge about how they work and learn; and that socio-technical interventions that aim to be successful in
making learning easier, more effective, more enjoyable etc. need to be based on both backgrounds.

Hierarchical Evaluation Methodology
Field studies in all research streams were evaluated along a hierarchy, inspired by Kirkpatrick’s hierarchical framework for evaluating training programs in organisations (Kirkpatrick & Kirkpatrick, 2010). 

Evaluation dimensions were 1) reaction – how were technologies actually used, how did relevant activities of users look like during the intervention period? How did users react to the overall intervention? 2) learning – which insights were gained throughout the intervention period 3) behaviour – which changes in behaviour were implemented, experimented with during the intervention, or planned for after the intervention 4) results – what is the expected, or evidenced impact on the overall organisation? This overarching methodology for all field studies is also described in (Renner et al., 2019OWN, including used scales in the paper appendix).

Research Streams
The below description of design, development and evaluation of socio-technical interventions is structured as follows:
Firstly, three research prototypes that have been designed in user-centered design processes evaluated in field studies are presented (KnowSelf, MoodMap App, Medical Quiz – Section 5.1). They instantiate different design concepts. Both KnowSelf and the MoodMap App instantiate the concept of data-driven technologies for reflection, with KnowSelf using automatically tracked data and the MoodMap App using using manually tracked data. Both include reflection guidance. The Medical Quiz deviates from data as basis for reflection, and embeds reflection in the playful learning activity of quiz-playing. Secondly, field studies in which these prototypes were part of the tested socio-technical are summarized (KnowSelf - Section 5.2, MoodMap App – Section 5.3, Medical Quiz – Section 5.4). The data gathered in these field studies have also been meta-analysed together with data from other researchers’ field studies (Renner et al., 2019OWN).
Thirdly, a computer-mediated reflection guidance concept is described, which is based on Schön’s concepts of reflection before/in/after action and also includes adaptive reflection guidance elements (Section 5.5). The concept has been instantiated in all three research prototypes, and this instantiation is described within the same section. The concept has been in use in several of the field studies described in Sections 5.2, 5.3 and 5.4. Evaluation results are reported together with the corresponding field study in Sections 5.2, 5.3 and 5.4 in this habilitation, and are synthesized across field studies both in the discussion in Chapter 6, and in (Fessl, Wesiak et al., 2017OWN).
5.1 Research Prototypes

**KnowSelf: Activity Logging Research Prototype**

As technical basis for this research stream, an activity logging research prototype, KnowSelf, was developed (Figure 1, Pammer, Edler & Stern, 2012). KnowSelf collects time-stamped PC activity data, linked to web or file resources, and identifies idle times. As core innovative feature at the time, the tool visualizes the fragmentation of worktime similar to the Windows disk fragmenter. By now, such a visualization is already integrated in commercial tools like ManicTime. Fragmentation of worktime is a relevant dimension for reviewing own time use with respect to time management. It has been shown that knowledge workers' time is typically severely fragmented by interruptions (Mark et al., 2005). Such interruptions severely impact productivity (Czerwinsky et al., 2004; Mark et al., 2008) and lead to stress (Mark et al., 2008). KnowSelf supports manual time labeling to sort automatically logged data into categories that are meaningful to the user (e.g., project names). Labeling is useful to record non-digital activities and to provide higher-level names to activities that span multiple resources. The research prototype has note-taking functionalities, and provides visualizations of time use around resources, applications and tasks.

![Activity Logging Tool - Research Prototype](image)

Figure 1: Activity Logging Tool - Research Prototype: The default tab gives an overview of the following: 1) Fragmentation of worktime is represented. 2) shows a sortable list of timespan and digital resources in focus. 3) visualises the overall time spent on a day per application. 4) gives an overview over multiple days with time fragmentation per application, and 5) shows how much a selected resource has been used over time (the rationale being, that some documents are relevant only for a short period of time, [link](http://technet.microsoft.com/en-us/library/bb742585)).
while others are frequently used but shortly). Other tabs give analysis per application, per project, and the possibility to take notes.

**MoodMap App: Mood Self-Tracking Research Prototype**
The mood self-tracking research prototype (MoodMap App) that we developed as part of this research stream represents moods along the two dimensions of Russell’s Circumplex Model of Affect (Russell 1980), which are valence (feeling good–feeling bad) and arousal (high energy–low energy). Interfaces following this model have been investigated and validated in previous researches (Mora et al. 2011; Morris et al. 2010; Ståhl et al. 2005). Our visual representation of mood is similar to these visualisations.

Note that while we labelled the self-tracking application “MoodMap App”, we didn’t strictly stipulate users to track mood in the sense of longer-term, diffuse affective states as opposed to emotions in the sense of affective reactions to events: The goal was for users to capture their current affective state as seemed relevant in their context of use.

Mood in the MoodMap App is captured by clicking on the bi-dimensional mood map (Figure 2 - a) based on Itten’s colour system (Itten, 1971). Personal notes (free text) can be attached to mood entries and context information can be added outside of mood entries (e.g., a task has been finished). Moods, notes, and context are aggregated and visualized in different views on an individual as well as collaborative level. At the team level, the average mood of each team is calculated with the last mood of each user captured in the present day.

Finally, note that the MoodMap App was adapted in user-centered design iterations prior to longer-term field studies; and therefore different versions were trialled in the virtual team setting (see this section below), the call center setting (see this section below, and Section 5.4); and in the IT company setting (see Section 5.4). In addition, also a mobile version of the MoodMap App has been developed as technical study in HTML 5, but this version has not been part of a field study.
Figure 2: MoodMap App research prototype - (a) Mood can be entered (=captured) by clicking on a coloured, bi-dimensional mood representation. The entered mood is also translated into a smiley. (b) In the Compare Me View, own average valence (feeling good/bad) and arousal (high energy/low energy) is compared to average valence and arousal of group. (c) In the Collaborative View, current mood of all others in the group are shown. Different versions of the MoodMap App show this anonymously or with names. (d) A mood report summarizes captured mood over some time. Different versions of the report were experimented with. The shown report in the above figure shows for instance the development of valence and arousal over time (left bottom corner), gives contextual information about the meeting, lists full-text notes given in addition to mood entries, and separates the mood map into four quadrants, showing how many moods were stated in which quadrant (right top corner).

Medical Quiz: Reflective Quiz Research Prototype
The quiz was implemented based on the open source eLearning platform Moodle\(^6\), i.e. it is a web-based quiz that runs in every standard web browser. Four different quiz types were created: A Quiz-of-20 a Quiz-of-10 and a Quiz-of-5 with twenty, ten, and five questions respectively; and a Quiz-against-time in which the goal was for players to answer questions as fast as possible. The quiz contained both content questions, which tested for knowledge relevant to stroke nurses, and reflection questions (=prompts; as all prompts in this case had the form of open questions, we refer to these prompts as reflection questions). Reflection questions were designed by researchers as reflection guidance, i.e. as means to incite reflection. First, there were reflection questions at the beginning of each quiz which related to learning,

---

\(^6\) https://moodle.org
based on previously played quizzes and play frequency. An example of such a question is “You are very motivated and you play the quiz at least once per week - you results are really very good. What is your success recipe?”

Secondly, reflective questions were interwoven with content questions which related the theoretical knowledge of the content question to past and future work behaviour. An example of such a question is “Does the question posed above remind you on an interesting situation or discussion during the qualification programme or during work. If yes, which one?” A full list of reflection questions is given in Fessl et al. (2014OWN, p. 5). Note that in each quiz, only a low number of content-questions was enhanced with in-between reflection questions (two in the case of the Quiz-of-20). Figure 3 shows a content question and such an in-between reflection question. Thirdly, there was a reflection question at the end of the Quiz-of-20, Quiz-of-10, and Quiz-of-5 which asked more in general about gained insights and changed perceptions with respect to work practice.

While the quiz technology is of course domain-independent, domain-specific content needed to be created. In the field trial, the quiz contained 142 content questions which had been developed by the leader of the qualification programme for stroke nurses, as well as stroke nurses and physicians of the stroke ward that hosted the programme. For long-term usage, quiz content would need to be continually updated – this was an issue that we didn’t further address within our own research.
5.2 Activity log data as basis for improving time management
The ability to self-manage time is one of the key challenges for knowledge workers (see e.g., Mark et al., 2008; Wu and Tremaine, 2004). Time management (TM) means activities like assessing, planning and monitoring time use with the goal to organize time use in a productive and healthy manner (see e.g., Claessens et al., 2005). Commercial activity logging tools like ManicTime\(^7\), RescueTime\(^8\) or SLife\(^9\) already claim to support time management. Scientifically however, the usefulness of activity logging tools for (learning about in the sense of improving) time management is surprisingly under-explored. Automatic activity logging has already been used to measure the behaviour of study subjects, investigating for instance the cost of task interruption (Iqbal and Horvitz, 2007) or work patterns dependent on daytime, weekday or location (Begole et al., 2002). Only more recently, time-stamped data have been

---

\(^7\) [www.manictime.com/](http://www.manictime.com/)
\(^8\) [https://www.rescuetime.com/](https://www.rescuetime.com/)
\(^9\) [www.slifeweb.com/](http://www.slifeweb.com/)
investigated also as means to support time management. Dugan et al., 2012 explored which visualizations and analyses of calendar data would be helpful for time management (21 participants). The authors note, that participants were missing “actionable analytics” in data, i.e. analyses and interpretations of data that would help them decide on future behaviour. Kocielnik et al. (2018a) take a approach to supporting reflection on, and improving, time management in that they designed for manual and achievement-based tracking versus tracking of actual time use.

Activity logging as computer support for time management is related to the wider research on personal informatics and quantified self (see above on data-driven reflection). Manually or automatically created activity logs in this context serve the purpose to provide a data basis beyond memory for re-evaluating experiences (Choe et al., 2014; Krogstie et al., 2013OWN; Li et al., 2010; Li et al., 2011).

**Research Goals**

In this research stream, the goal was to understand the role and value of activity log data in learning about and improving own time management of knowledge workers.

**The Surprising Fragmentation of Worktime**

A study with seven IT and strategy consultants\(^{10}\) was carried out (Pammer & Bratic, 2013OWN), in which participants used KnowSelf as described above, but without proactive reflection prompts, over a period of two weeks. Participants tracked their time automatically with the research prototype, additionally labelling time spent on particular tasks, and were asked to review their time use daily. In the end, participants had not reviewed their time use every day as had originally been planned, but all participants had done so at least multiple times a week.

The study confirms the baseline assumption of this research stream that activity log data helps to identify patterns of time use, such as self-interruptions by email, and to monitor intended time management practice, such as times set aside for focussed working. A key emerging theme in analysis was that study participants were **surprised about the extent of work time fragmentation**. The latter complements Mark et al's (2005) study which finds their study participants to work on average 11 minutes without interruption in one “working sphere” (~task), as our study **highlights that knowledge workers may not be aware of the extent of worktime fragmentation**.

**Learning about Time Management and Experimenting with Time Management Strategies**

Subsequently, two longer-term studies were carried out (Pammer et al., 2015OWN).

\(^{10}\) 11 consultants initially volunteered for the study; seven completed the study (see Pammer & Bratic, 2013OWN).
In one study (Study 1; N=10), participants used KnowSelf for time tracking. In addition, participants were instructed to review their time use daily, and to take notes of insights and plans for change (individual reflective practice). In the other study (Study 2; N=10), participants did the same, and additionally received weekly bilateral coaching (collaborative reflective practice in addition to individual reflective practice). In both studies, interventions took place for six weeks alongside normal work, and in both studies, study participants were IT and strategy consultants in medium-sized companies in Western Germany. Each study was set in a different company.

Evaluation tools in both studies were questionnaires on time management skills and behaviours pre and post the intervention (5-point Likert scales), insights and changes in/experimentation with time management behaviour post the intervention with a questionnaire that contained both 5-point Likert scales and open questions, short weekly interviews with study participants, and post-interviews. In Study 2, an additional questionnaire was used to assess the quality of coaching.

The socio-technical intervention in Study 1 consisted of the research prototype for activity logging as described above, and individual reflective practice. Participants were instructed to have the activity logging tool (AL tool) running on their PCs in the background throughout the study and to manually label time whenever they found this useful (self-tracking). Participants were further instructed to review their time use in the AL tool daily and to write down insights and plans for change (reflective practice). The socio-technical intervention in Study 2 consisted of the same research prototype for activity logging as described above for half of the study participants, of ManicTime for activity logging for the other half of the study participants; and of individual reflective practice as above for all participants; as well as bilateral weekly coaching on time management in addition.

In both studies, participants reported reasonable insights about their own time management, and reported experimenting with reasonable time management strategies in post-interviews. The short summary of the two studies is therefore: Both interventions, which are socio-technical interventions with activity logging as technical part of the intervention, and individual reflective practice in Study 1, and individual plus collaborative reflective practice (=coaching) in Study 2, worked. For Study 2, we could even show that study participants improved their self-assessment with respect to predefined time management best practices significantly.

In exploring the particular usefulness and limitations of activity logging and activity log data, we firstly confirmed that the main benefit of automatic activity logging lies in providing accurate information about time use with only optional additional effort (manual recording of tasks/projects if desired). We also identified that participants had missed systematic peer exchange: A more formal framing, guidance or motivation to exchange experiences would have been welcomed, above the informal opportunity to do so. In addition, neither AL tool had social software features like sharing comparing one’s data with peers’ data, messaging, or discussion forums. Thereby, AL tools pre-
conceived learning about and improving time management as individual and private activity. Such functionality however could have helped participants, especially in Study 1 (only individual reflective practice, no coaching), to interpret data with respect to time management best practices, to develop strategies for changing time management behaviour, and to commit to intended behaviour change openly.

From the perspective of own contributions to design-oriented theoretical considerations on reflection, this would mean to design for systematically inviting others in to reflection in order to give input or advice (cp. Prilla et al. 2013\textsuperscript{OWN}), even when the scope of reflection is individual, i.e. people reflect to mostly on things within their own sphere of influence.

Secondly, we identified that participants had generated fewer and fewer insights from activity log data over time, especially in Study 1: This is natural as time management behaviour overall can be expected to be consistent for a given person over time. This finding can also interpreted as being in line with the call for “actionable data analytics” (cp. Pammer & Bratic, 2013\textsuperscript{OWN}; Dugan et al., 2012 in relationship to time management) and to make data interesting for a longer period of time (cp. Kocielnik et al., 2018b in the context of physical activity logging). From a learning sciences perspective, this would mean to move from conceiving technologies for data-driven learning as self-directed, in principle un-instructed, learning to understanding it as part of an instructionally designed learning environment. Following Kirschner et al.’s (2006) criticism of such minimally guided learning environments, suggestions for such a change in conception would include background knowledge about the domain as well as background knowledge in how to progress in the learning domain (learning strategy). One way to go forward with analytics-based tools therefore could be for socio-technical interventions for learning to offer i) support for data interpretation with respect to the learning domain, and ii) advice on strategies for learning and changing behaviour.

Reminders to reflect using the research prototype (prompt to action), and information about most used resources as basis for reflection (prompt to reflect) were perceived as useful (cp. Fessl, Wesiak et al., 2017\textsuperscript{OWN}, p. 11).

Proactive prompts (even those with self-set timing) were sometimes perceived as disruptive (ibid, p. 12).

The above results are a novel result with respect to time management and activity logging in particular. As characteristic that is maybe particularly salient in workplaces, and may therefore be less present in related work situated in private areas of life, we identify that systematic peer exchange is strongly desirable for study participants.

5.3 Mood self-tracking as basis for reflective learning
Mood is in the top five of the most popular items tracked by Quantified-Selfers (Choe et al. 2014) and numerous applications for mood tracking exist. Also in our own work, informal design-oriented workshops with users elicited a high interest of users in mood tracking and reflection on or in relation to mood.
Initially, we had also explored the possibility of using sensors to automatically capture affective states via physiological sensors (Fessl et al., 2011\textsuperscript{OWN}). However, participants were largely sceptical about practicalities of wearing sensors at work, and about the relevance of automatic detection of affective states (as we would have to assume that detection would not be perfect) in comparison to self-tracking. We therefore developed this research stream into investigating mood self-tracking as basis for reflective learning.

We understand mood as more diffuse than emotions and with a less clear cause, longer in duration and less focused and intense (Frijda 1994). Emotions are affective reactions to an event, typically short-lived and directed at a specific object or event, whereas mood is a longer term affective state. Emotions can contribute or influence the mood of an individual, and inversely moods tend to affect which emotions are experienced (Brave and Nass 2003).

Russell (2003) highlights the connection between these two by emphasising that people experience emotion, mood, and emotionally charged situations simply as states of feeling good or bad, energized or enervated. This understanding is captured in Russell's two dimensional model of affect (Russell, 1980), which describes affect along the two dimensions valence (feeling good–feeling bad) and arousal (high energy–low energy). With respect to modelling mood, we based our design on this model.

In relation to reflection, Boud et al. (1985) highlight that past and present emotions need to be carefully considered in reflection, as they might point to salient aspects of that which is reflected on. Inversely, reflection can increase awareness of own emotions (see e.g., Morris et al. 2010). From a design perspective, different ways of mood tracking and representing mood to support awareness and reconstruction of the emotional memory have been studied in HCI previously (Church et al. 2010; McDuff et al. 2012; Ståhl et al. 2009; Sundström et al. 2007).

In collaborative settings, awareness of others’ emotions has been shown to enable users to respond accordingly and subsequently to achieve better results in collaborative work (García et al. 1999). This complements the knowledge in computer-supported cooperative work that awareness of significant information about others is beneficial in collaborative work settings (Gutwin and Greenberg 2002).

**Research Goals**

Therefore, existing literature indicates that collaborative mood tracking could both support reflection about individual aspects of work, as well as support collaborative work. In this research stream, the goal was to **understand the role and value of self-tracked mood in collaborative settings**, with an initial assumption that it would serve to increase awareness about others’ emotions, and thereby positively impact collaborative work.

**Mood Self-Tracking in Virtual Meetings**

Mood self-tracking as means to support collaborative work was first trialled in a spatially distributed team of 12 people (Fessl et al., 2012\textsuperscript{OWN}) to support
remote, computer-mediated team meetings. The research prototype was used in four team meetings within the same team.

The goals of this study were to investigate usability and usage of the MoodMap App in a workplace setting, and to assess the impact of collaborative mood self-tracking on collaboration and communication in virtual team meetings.

The field study was carried out in a spatially distributed team of 12 consultants working for a European telecommunications company. The MoodMap App was used in four team meetings, in which users were asked to enter their mood at least in the beginning and at the end of the meeting. A short questionnaire on the overall meeting atmosphere, participant's role in the meeting, and insights gained via mood tracking was answered in every meeting. A final questionnaire elicited retrospective impressions on the usefulness and benefits of mood tracking during virtual team meetings. In addition, post-interviews were carried out with six of the team members in order to discuss main points found in the questionnaires.

The MoodMap App itself was found to be easy and intuitive to use. Most study participants found mood tracking to be useful by increasing awareness of own mood, but some found this to be less interesting as they perceived them to know their own mood sufficiently well even without tracking. There was agreement that the mood of others was indeed interesting, facilitated communication, and served as trigger to reflection on collaboration within the team. In particular, the Compare Me view (comparison of own mood with average mood of others) was found to be interesting. On the other hand, participants missed a systematic way to collect contextual information about single mood entries, and a systematic way to collaboratively reflect on mood data. Subsequently, the functionality to capture contextual information for mood entries was added to the MoodMap app both via pre-defined contexts (drop-down menu) and free text.

**Mood Self-Tracking in Call Centers**

Subsequently, a study in the same European telecommunication company, but in business-2-business call-center teams was set up (Rivera-Pélayo et al., 2017OWN).

Call takers are responsible for incoming requests for product support and information inquiries. The work of call takers is mainly based on individual working routines (e.g., answering a customer call). At the same time, call takers are part of teams working together. This structure offered us the possibility to investigate the impact of mood self-tracking both on individual performance and team working atmosphere.

Prior to the field study, a participatory design iteration was carried out in order to adapt the MoodMap App to the new use case, and to design usage of the MoodMap App in a manner meaningful to the new use case setting. The design activities consisted of a visit to one call center, and a preliminary field trial of four weeks within two teams (two managers, five coaches, ten call takers). This design iteration led to an adaptation of the MoodMap App that i)
shortened the click-path to capture moods, ii) added functionality to add contextual information to mood entries, and iii) de-anonymised mood entries, which made it easier to contextualise mood entries in retrospective reflection (reflection on action). A detailed description of changes is found in Rivera-Pélayo et al., (2017, p. 11). In addition, the preliminary study led to an elaboration of the intended pattern of usage for the field study, namely that i) mood would be captured by call takers before and after calls; ii) mood would be reviewed during coaching sessions (available to call takers within their standard work environment, i.e. not specifically added for the purposes of this study), and captured during and after coaching sessions; and iii) managers would review mood of their team as part of their routine work process.

Ultimately, a four-week field study was conducted in two different call centers, each of which participated with two teams. All teams and participants used the socio-technical intervention (adapted version of the MoodMap App and the usage pattern) that was designed as result of the preliminary field study. Evaluation tools were a pre- and a post-questionnaire (41 and 38 respondents respectively), interviews with two call takers and one manager directly after the field study, a measurement of call center key performance indicators before, directly after, and one month after the field study (available only for one of the two call centers), and the log data from the MoodMap App. The Compare Me view was the most used reflection view in the App. This is in line with our findings in the virtual team meetings study. Together with log data and data from questionnaires and interviews, we understand that the **curiosity of people to gain awareness of others’ affective states motivates users to track their own mood**. Beyond this, **shared mood data served to improve communication within the teams**, and particularly also between call takers and managers. By increased awareness of overall team mood, and individual team members’ mood, managers were enabled to react quickly to needs of individual team members. This is especially important as managers were not co-located with their teams (separate offices) in our field study. Conversely, this benefit of collaborative mood tracking can only materialise where also management actively buys into collaborative mood tracking by allowing it to shape own behaviour: In two of the four teams, managers didn’t actively react to tracked mood, and in those two teams, also overall usage and perceived benefits were low. We therefore understand **collaborative mood self-tracking to have functioned as providing triggers for offline peer and managerial support, and overall communication within teams**. Finally, in the team with the highest engagement with the MoodMap App, we could also show a statistically significant increase in measured average rating of call takers (a call center key performance indicator, which is the rating given to an individual call taker by the served customer). The field study therefore also shows an impact of collaborative mood self-tracking on work performance.
5.4 Game Play: Reflection Guidance in a Quiz for Stroke Nurses

Games are our brain’s favourite way of learning (Prensky, 2001) and are an effective means to attract attention and retain interest as they can be simultaneously entertaining and instructive (Bontcheva & Vassileva, 2010; van Eck, 2006). Hence, game-based learning is typically found to be an effective means of learning (Van Eck, 2006). In this research stream, we investigate a serious game, concretely a quiz, that includes reflection guidance. By serious game, we here understand “a game in which education […] is the primary goal, rather than entertainment” (Michael & Chen, 2006).

Especially quizzes are widely used in technology enhanced learning, as they constitute a well-known way of playing (Bontcheva and Vassileva, 2010). They are also suitable for formative assessment within the context of formal learning (Hudson and Bristow, 2006; Koch et al., 2010), and have been shown to improve performance on summative examinations (Kibble, 2007). Furthermore, learning can also be encouraged by involving learners in the creation of content for quizzes (Pollard, 2006), or by adding meta-cognitive questions that motivate students to reflect on, and monitor their own learning (O’Hanlon and Diaz, 2010).

All empirical work of this research stream was situated in the context of nurses specialised on care for stroke patients. Nursing is generally understood as a knowledge-intensive practice discipline, i.e. it can only be learned in a combination of theory and practice (Papastavrou et al., 2010; Tiwari et al., 2006). In parallel, it is also understood that the up-take of new, theoretical knowledge into nursing practice is challenging (Estabrooks, 2003; Nilsson Kajermo et al., 1998; Wallin et al., 2003). In nursing education, a variety of game-based technologies have been successfully investigated, such as simulations (Petit dit Dariel et al., 2013; Stanley & Latimer, 2011), strategic board games (Mann et al., 2007), or quiz games (Boctor, 2013). This mirrors the more general understanding that both “the acquisition of knowledge through research and learning” and the “application of knowledge to current problems” are inherent part of knowledge work (Kelloway & Barling, 2000 p. 292), concretising it to the profession of nursing, and specifying that neither is an easy task.

Research Goals
Overall, prior work therefore strongly indicates that a quiz on a relevant topic for the target users that includes reflection guidance, i.e. questions that aim to incite reflection, would be able to support learning. However, prior work with nurses has been to a large degree set in the context of higher education. With this research stream the goal was to investigate the acceptance of game-playing by knowledge workers, the possibility to integrate game-playing in work practice, and the possibility of using reflection guidance to stimulate a transfer of knowledge between theory and work practice.

In a design workshop with decision makers at the targeted stroke ward, as well as with the leader of a formal qualification programme hosted at the same stroke ward, the concept of the reflective quiz as well as two different types of
usage scenarios and patterns were elaborated: Firstly, the reflective quiz should be used by stroke nurses during their shifts in the absence of other tasks (especially night shifts seemed suitable). Secondly, the reflective quiz should be used to support the formal qualification programme, which ends with an exam and a certification in case of success.

**Design Study on the Reflective Quiz as Support for Informal Professional Learning**

One study in this research stream explored usability, acceptance, and viability of the reflective quiz as support for informal professional learning, i.e. its usage at work (Fessl et al., 2014OWN). Note that in this study, the quiz didn’t have shorter quizzes (Quiz-of-10, Quiz-of-5), nor did it have reflection questions at the beginning and the end.

Immediately several practical challenges appeared at the beginning of this study: Internet access was not available at the PC in the ward, software installation was forbidden by the central IT department, as the stroke ward was situated in the basement public network was not available, and as it counts as an emergency ward, a dedicated WiFi network could not be set up. It was therefore decided to start with a design study.

Eight nurses (1 male, 7 female) participated in the design study. Nurses individually tested the quiz in a separate office during work time. Demographic information was collected before the quiz, and a questionnaire and interview were conducted after the quiz.

Nurses perceived the quiz as usable, useful for learning, and motivating. Nurses also perceived the quiz as strengthening self-confidence, in the sense that they could see that they were up-to-date. Also reflection questions were well perceived and understood to be relevant. Note that this didn’t necessarily mean that participants actually filled out the text fields in the research prototype; participants often simply thought about the question.

Results were less encouraging with respect to the viability of including game-playing in work practice: Although nurses would in principle regularly have some (short) time to play a quiz, especially during night shifts, usage of the quiz would need to be on nurses’ private smartphones due to severe restrictions on what can be installed on hospital computers. However, being seen to be “playing around” with a personal smartphone was perceived as socially not acceptable by nurses; and nurses did not have private space for such learning. Usage of the reflective quiz as part of a socio-technical intervention for informal professional learning was therefore not further investigated.

**Reflective Quiz as Support for Formal Qualification Programme**

In parallel to the above study, we carried out a design study on using the reflective quiz as support for a formal qualification programme hosted at the same stroke ward (Fessl et al., 2014OWN). The design study was followed-up by a field study that ran for three months in parallel to one instance of the
 qualification programme (Fessl et al., 2016\textsuperscript{OWN}; Fessl, Wesiak & Pammer-Schindler, 2018\textsuperscript{OWN}).

In the design study, nineteen nurses (6 male, 13 female) trialled the reflective quiz individually, and discussed the quiz in a group (split into two groups). Mirroring the above design study, the quiz was found to be usable, useful and motivating. In order to check results on viability of integrating with work, this issue was also discussed with nurses in this design study; and participants largely agreed in being highly sceptical of integrating game-playing in work practice. One additional concern in relationship to game-playing at work that was brought up was the fear to fail at the quiz, and this being visible to colleagues. On the other hand, study participants were positive about using the quiz individually alongside the qualification programme, and expected that the quiz would help them refresh knowledge, close knowledge gaps, and appropriate new knowledge. The quiz was seen as a learning method without grades and pressure – thus presenting a safe environment for learning.

Subsequently, the reflective quiz was used as learning tool in a qualification programme, which consisted of four course weeks spread over three months, with working weeks for the nurses in between courses. Twenty-one nurses (2 male, 19 female) participated in the qualification programme, and in this study. Evaluation tools were a pre-questionnaire in the first course week, shorter in-between questionnaires, a post-quest questionnaire and group discussions as well as post-interviews in parallel to the last course week. Overall, the socio-technical intervention worked: Study participants used the quiz significantly in parallel to the qualification programme, and found the reflective quiz to be useful as means to prepare for the final exam. Some participants self-reported having actively experimented with integrating novel knowledge into work practice, motivated by reflection questions.

Timing of reflection guidance was found to be important, also in this context: Reflection questions directly within the quiz were perceived as disturbing the flow of game-playing. This shows that even in settings where the time has been set aside for learning, reflection may not necessarily be suitable directly within the learning activity. The study shows that an inclination to reflect correlated significantly with the perception of usefulness of the reflective quiz (Fessl, Wesiak & Pammer-Schindler, 2018\textsuperscript{OWN}, p. 10). This highlights that the meta-competence to reflect is a necessary prerequisite for socio-technical interventions for reflection to work.

Finally, we found that reflection questions were not answered within the tool (as we did in the design studies); but questionnaires, post-interviews and group discussions indicated that participants were incited to reflect via the questions, and could relate theoretical knowledge to their work practice. This highlights that researchers need not necessarily be discouraged if traces of reflection cannot be found in written notes; and at the same time highlights the difficulty in proving that reflection has taken place in field studies.
5.5 Computer Mediated Reflection Guidance

Reflection guidance technology aims to trigger and structure reflection, with the ambitious vision to mentor the learner (cp. Dimitrova & Brna, 2016, who calls “intelligent mentoring systems” one of the emerging directions for intelligent tutoring systems research). The present state-of-the-art, and also own research, is of course far from replacing a human mentor. It is, however, able to support learners in complex and ill-structured learning settings such as workplaces. This has been shown in own empirical research: As part of this habilitation, a reflection guidance concept for computer-mediated reflection has been developed and grounded in foundational theory of reflection (Schön, 1983). The concept has then been instantiated in three research prototypes (KnowSelf, MoodMap App, Medical Quiz). These instantiations have been evaluated in terms of usage, usefulness and effect on learning across field studies (Fessl et al., 2015OWN; Fessl, Wesiak et al., 2017OWN). This section contains an updated description of the reflection guidance concept and clarifies how the concept was instantiated in the research prototypes KnowSelf, MoodMap App, and Medical Quiz. This section doesn’t report results of field studies however, these are presented per field study in Sections 5.2, 5.3 and 5.4, and overarching insights are presented in the discussion (Chapter 6).

Research Goals

The research goals were to develop **adaptive reflection guidance technology** that is shown to achieve usability and user acceptance, and a **positive impact on learning** (plausible insights are generated) and **behaviour** (at least: experimentation with new work practices) in field trials in workplaces - something that didn’t exist at all in related work at the time this research stream was started. By now, Kocielnik et al (2018b) have published a field study on a prototype that takes a different approach (no unguided data collection), but definitely constitutes reflection guidance in a workplace setting. Note that the research focus was on adaptive reflection guidance, i.e. technology that adapts to a user’s work and reflection activities as well as to content of the tool used for reflection. The overall concept is nonetheless wider and concerns computer-mediated reflection guidance, as it was based on a reflection theory (Schön, 1983), and not on a particular type of technology (adaptive technology).

Reflection-in-Action Components

Schön (1983) defines reflection-in-action as reflection that is intertwined with operative work such that the action on which one reflects can still be impacted by the outcome of reflection. Such reflection is understood to be immediately and inseparably embedded into action. Consequently, reflection-in-action components aim to trigger reflection during operative work. Reflection-in-action components can be proactive prompts, or cues which are visible or otherwise accessible during work. Proactive prompts have been implemented in KnowSelf and the MoodMap App in the form of pop-up windows, as directly
embedded into the activity in the Medical Quiz (quiz questions), and as more discrete visual cues in a sidebar in ongoing work on enabling reflective search (Fessl, Wertner & Pammer-Schindler, 2018OWN; Fessl, Pammer et al., 2017OWN).

We have implemented two types of reflection-in-action components: *Prompts for action* are prompts that motivate users to do something; typically to use the app into which reflection guidance is implemented. These prompts serve as a reminder to reflect, and direct users towards an environment in which reflection is further supported. They are typically either adaptive with respect to tool usage; or scheduled (e.g., a reminder every Monday, 1pm). These prompts are similar to what is called “activity prompts” by Davis (2003), which have the more fine-granular goal to facilitate the completion of specific aspects of an activity.

*Prompts for reflection* directly refer to content or data that is available within the app in which reflection guidance is implemented; and aim to incite reflection about this content or data. Such prompts for reflection are in line with what is called “reflection amplifiers” by Verpoorten et al. (2011), who describe reflection amplifiers as providing “a structured opportunity to examine and evaluate their own learning”. They are similar to what is called “self-monitoring prompts” by Davis (2003), which are questions or sentence starters to initiate reflection with the goal of knowledge integration when answering these questions.

**Reflection-on-Action and Reflection-Before-Action Components**

Schön (1983) defines reflection-on-action and reflection-before action as reflection temporally clearly separated and distinguishable from the action that is reflected on. The former has a strong relationship to past action, and the latter a strong relationship to future action in the sense that there is a concretely expected future experience that one aims to shape through reflection. Consequently, “reflection-on-action” or “reflection-before-action” components are in general “places” in apps that aim to motivate and enable users over a broader range of data and content.

One kind of reflection-on-action component is a *reflection diary*, which gives a structured possibility to describe thoughts and insights. A second kind of reflection-on-action /-before-action components are *automatically created summary reports* of data, and more in general *aggregate views and data analyses* of captured data. Both types are available in all three research prototypes (KnowSelf, MoodMap App, Medical Quiz).

A third kind of reflection-on-action /-before action component is technology that is able to *import and integrate data from multiple sources*. We have developed a research prototype that combines data from PC-based activity logging, mood self-tracking, and location-based note taking, and allows data visualisations to be created interactively by users at usage time. In a study based on real data collected by three users throughout two weeks, we could show that the interactive combination of data is usable, and is capable of
inciting users to generate relevant insights that go beyond what is possible with using single data sources (Luzhnica et al., 2016\textsuperscript{OWN}). Finally, also proactive prompts for reflection can serve as reflection-on-action, depending on whether the data they refer to was close to the time of prompting, or not (see as example the description of time-triggered prompts in Section 5.2 above).

**Contextualisation Components**
Contextualisation components enable users to capture additional information in an app which is useful or even necessary to make sense of the main data captured within the app. Such context creates meaning of data, that is very focused in what it represents, in relationship to a more overarching, meaningful activity of the user (cp. Dourish, 2004). Examples of contextualization components in own research prototypes are the labelling functionality in the activity logging research prototype KnowSelf; and the contextual notes (both drop-down, and free-form) that can be attached to mood entries in the MoodMap App.

**Instantiating the Reflection Guidance Concept**
This section highlights how the different types of reflection guidance were implemented in the three research prototypes KnowSelf, MoodMap App, and Medical Quiz.

*Reflection guidance in KnowSelf*
KnowSelf mostly supports reflection-on-action (Schön, 1983) as all views represent computer activity over time (Figure 1 - 1,2,4,5) or aggregate data per application or resource (Figure 1 - 3,4,5). In addition, we can also understand the reflection diary (an overview over all notes taken) as reflection-on-action support. Labeling, in terms of support for reflection, is a contextualization component that constitutes an entry point for reflection-in-action, as by giving a meaningful name to what one is currently doing one already categorizes and briefly reflects ongoing experience. Finally, KnowSelf also contained proactive prompts for reflection: One type of reflection prompts was time-triggered, with the time decided on by users, e.g., every Friday at 3pm. Such prompts for reflection could constitute both reflection-on-action and reflection-in-action, depending on the temporal relationship between the reflection prompt and the data referred to inside the prompt. The second type of reflection prompts was event-triggered, i.e. timing was adaptive to user activities, e.g., when the number of application switches is higher than usual, or after longer than usual periods of idle time (cp. Fessl, Wesiak et al., 2017\textsuperscript{OWN} p.6; and Figure 4 for an example reflection prompt in KnowSelf). This type of prompts therefore constituted reflection-in-action.
Reflection Guidance in the MoodMap App

In the MoodMap App, visualizations were designed to support reflection-in-action and reflection-on-action as defined by Schön (1984) and Munby (1989). With respect to reflection-in-action, three live visualizations aimed at providing feedback and allow users to see the development of own and others’ mood live: My Timeline, Compare Me, and Collaborate. The “My Timeline” visualization presents development of own mood during a day on a timeline. The “Compare Me” visualization (see Figure 2 - b) allows to compare own mood with the average mood of a group in the two mood dimensions valence and arousal. For each dimension, the blue arrow on the left represents the user’s value, and the black arrow on the right shows the average value of the group. By moving the mouse over the arrows, the user gets more information about the current number of participants. The “Collaborate” view (see Figure 2 - c) presents the average mood of the team through a red cross as well as each single mood point of all team members anonymously. This allows users to visualize the moods of the team’s colleagues and identify potential clusters and deviations.

In order to support reflection-on-action, a report summarizes the mood tracking of a working day, or meeting (depending on use case settings, this report was slightly adapted) to facilitate a retrospective overview and reconstruction of past experiences (see an example in Figure 2 – d). The reports include general information about the temporal development of mood, the number of captured moods in each quadrant of the mood map, provide
general information about the set-up (e.g., meeting), free text notes, and poses reflection questions designed to trigger reflection.

*Reflection guidance in the Medical Quiz*
All reflection questions are temporally clearly separated from work, i.e. target reflection on and reflection before action. The reflection questions at the beginning of each quiz are related and adapted to the learning activity, not work practice. Also these question however are temporally separate from the past learning activities (playing the quiz), and separate from the next iteration of playing the quiz, i.e. we understand this again as reflection-on-action and reflection-before-action, and contains adaptive reflection guidance with respect to the learning activity.
6 Discussion

Chapter Summary:
This chapter synthesizes overarching insights of own research as follows:

• Beyond data: Even when the core concept of a tool for reflection is to use data as basis for reflection, manually curated materials within the tool are useful. They support i) the contextual explanation of data, ii) the documentation, explication, and persistence of reflection outcomes, and iii) the representation of the reflection activity, thereby also creating evidence for reflection. (Section 6.1)

• Sensitivity and confidentiality of data: These have been salient issues with respect to data-driven technologies in own empirical work; with completely different resolutions in different workplace settings (Section 6.2). Whichever the resolution, addressing potential sensitivity and confidentiality of data was absolutely necessary in own empirical work.

• When and where to reflect: Finding time and space for reflection has been found to be challenging. In that respect, the trade-off between automatic and manual data tracking is non-obvious: Manual tracking needs time, but also invites to reflection-in-action. Automatically tracked data doesn’t require time for data collection, but requires additional time for reflection-on-action (Section 6.3).

• What can reflection achieve? In professional practice, reflection needs to be expected to mostly not lead to ground-breaking insights. Professionals already have an adequate level of proficiency in their job. For them, reflection serves to continually fine-tune their competence and performance, with mostly small changes and updates to knowledge, perception and behaviour (Section 6.4).

• When designing for reflection in workplaces, the social dimension is extremely relevant, in the sense that reflection often involves multiple reflection cycles with varying reflection participants, and questions of power and division of labour are relevant. This characteristic in turn makes the systematic consideration of social software functionality at design time recommendable (Section 6.5).

• All of the above are salient characteristics of workplaces as specific contexts for designing for reflection that aren’t apparent in related work on data-driven and adaptive technologies for reflection carried out in other learning contexts (Section 6.5). This closes the thematic arch of the present habilitation, from setting out to add to literature on data-driven and adaptive technologies for reflective learning such research in workplace settings, to showing that such contexts indeed need specific attention, and highlighting a few of the salient characteristics.
6.1 Revisiting the Role of Data to Represent the Reflection Object

A key theme in the present habilitation is the role of data in reflection as representation of relevant aspects of the object of reflection. In this section I first discuss the implemented research prototypes from the point of view of how the reflection object is represented (by data or not) within them; and secondly outline how the concept of reflection object itself is useful, but could be further developed.

Data as Representation of the Reflection Object

Own research highlights, that professionals naturally reflect on aspects of work practice, and data need to represent or point to relevant aspects of this practice. Concretely, KnowSelf used automatically captured activity log data to represent the reflection object “time management”, the MoodMap App used manually captured mood data plus contextualising brief statements to highlight challenging cases of call center work, and the Medical Quiz represented relevant medical knowledge in the form of content-based questions and answers; and aimed to engage users in creating a representation of relevant parts of work practice by answering reflection questions.

Complementing the present work’s emphasis on data, manually curated materials ultimately played a significant role in all research prototypes: Prompts for reflection as well as contextualisation components in the concept for adaptive reflection guidance (see Section 5.1) have captured materials for reflection. Both were designed to give users a space to make explicit and persistent their thoughts about the reflection object. These thoughts at the same time can also be considered a representation of the reflection activity (=learning activity), as they present evidence about the quality and outcome of the reflection activity. This in turn was the underlying characteristic that was used as one indicator for reflection having happened in own empirical work, when analysing the content of free-text notes with respect to the depth of observed reflection (Fessl et al., 2017OWN; Rivera-Pelayo et al., 2017OWN).

Synthesising on yet one level higher, we therefore see that also in data-driven reflection, the reflection object is only partially represented by data. Most significantly, data don’t capture reflection participants’ thoughts and communications about the reflection object. For tool design and evaluation, this means that allowing humanly created artefacts within tools for data-driven reflection supports i) the contextual explanation of data and hence a more flexible representation of the (work-related) reflection object, ii) the documentation, explication, and persistence of reflection outcomes, and iii) thereby the representation of the reflection activity when participants’ changes in understanding of the reflection object becomes visible as temporal development.

In particular the contextual explanation of data and unstructured representation of the work-related reflection objects is relevant in work settings where the problems that professionals face are complex and ill-defined, such that a major challenge in such work is to frame and understand
the problem, and to identify a suitable solution approach (Rittel & Webber, 1973). In other words: where work practice is complex and knowledge-intensive, data can only constitute a partial representation of the reflection object; and more flexible representations suitable for encoding knowledge, such as natural language, are useful.

**Developing a Theoretical Grounding for the Reflection Object**

The concept of reflection object as I have used it in this habilitation is novel in comparison to related work: Of course, other authors in foundational theories of reflection (Boud et al., 1983; Schön, 1973), as well as in design-oriented theoretical works (Baumer, 2015; Fleck & Fitzpatrick, 2010; Li et al., 2010; Li et al., 2011; Slovák et al., 2017) or design works other authors implicitly understand reflection as being about something, but this is typically named in an exemplary manner “such as events”, or “experiences”. The concept of that which is reflected on is not conceptualised with respect to its role in reflection, as that which is thought about and changed through reflection. However, without this concept, it isn’t possible to clearly talk about the role of data for reflection for instance. A discussion as the previous on the role of data was made conceptually easier by having the concept of reflection object at hand. In an ongoing collaboration with my colleague, Michael Prilla, led by myself, I am now working on developing the concept of reflection object further by connecting it to the concept of an activity’s object from activity theory (Kaptelinin & Nardi, 2006), thereby giving the concept a theoretical grounding.

### 6.2 Sensitivity and Confidentiality of Data

One of the recurrent themes in the here presented research was the sensitivity of data with respect to system users (=knowledge workers), as well as with respect to clients of users, and confidentiality of data within the frame of the users’ employer organisations. Below, the two contrasting manifestations of this issue in our own studies are described and synthesised.

**No, no: Activity Log Data are Perceived as Highly Sensitive**

From the beginning on, we had understood automatically logged activity data as sensitive. Therefore, a threat analysis for activity logging was carried out (Pammer et al., 2014\textsuperscript{OWN}) and a distributed architecture that is capable of respecting users’ privacy with respect to their data was developed, both conceptually and technically. The architecture considers multiple data collection devices and a central server for data storage and analysis, in order to save space on users’ digital devices, allow combined analysis and visualisation of time use on multiple devices, and allow centralised data analysis. **Two different security configurations depending on whether local access to data is required or desirable** were conceptualised and implemented in a sensing framework, one with a private key only at server side, and one with a private key also at client side. However, in both studies described in Pammer et al. (2015\textsuperscript{OWN}) activity logging on multiple devices together with centralised storage and analysis had
been discussed with target users and user representatives prior to the field studies, and were strongly rejected by users. The main reasons were related to sensitivity of data. Firstly of course the data are sensitive with respect to individual users, and users were reluctant to allow logging on multiple devices, and central data storage (and combination of data).

This sensitivity of data with respect to users was also the reason why we were unable to implement a third field study using activity logging for time management in a non-German consulting team. In this team, organisational climate at the time of research was such that there was concern that data might in some way reach management and be used as reason to fire people\textsuperscript{11}. This highlights the relevance of considering the potential of data collected for reflection purposes as workplace surveillance in the sense of “monitoring and recording aspects of an individual or group’s behaviour […] for the purposes of judging these as appropriate or inappropriate; as productive or unproductive; as desirable or undesirable” (Introna, 2003; p.210). This also highlights the impact that organisational culture has on the uptake of learning interventions.

Beyond sensitivity of data with respect to individual users, there was also a concern that logged data were not only private to users, but also would contain data about clients (in filenames and task/project names for instance\textsuperscript{12}). In parallel, it was also argued that data could contain information that should be treated as organisationally confidential.

In order to still have potential access to data logged throughout the studies that involved activity logging, we implemented a purely local activity logger for Windows that was able to export data both in cleartext and in an anonymised manner in CSV. The anonymised export hashed filenames, manual labels, and notes, and left only timestamps and application names intact. Even with this anonymisation however, most participants in the end decided against handing out this data to researchers. While this was unfortunate from a methodological point of view, it is still understandable given the highly sensitive nature of data that lies not only in the cleartext but also in the pattern of activities throughout a longer period of time\textsuperscript{13}.

Balancing privacy and usefulness in the case of self-tracked mood data

Also in the research stream on self-tracking mood data, we were sensitive to the question of privacy from the beginning on. Initially, we had therefore designed all collaborative views in the MoodMap App to be anonymous. The field study carried out in the virtual team meetings (Fessl et al., 2012\textsuperscript{OWN}) used this anonymous version. On the other hand, this also impacted the

\textsuperscript{11} Naturally, confidentiality of data would have been guaranteed by researchers; however, potential target users felt that they had too little to gain by participating in a field study in comparison to what they could potentially lose.

\textsuperscript{12} The studies had been carried out before the European General Data Protection Regulation, but data captured by the activity logging tool would definitely be within the category of data about natural persons, and the regulation would therefore be applicable to the research prototype.

\textsuperscript{13} To the skeptical reader we recommend downloading a publicly available activity logging tool, running it for several weeks (or a day for starters) in the background, then looking at the data and considering sending it to a basically unknown person.
usefulness of this view, as knowing the author of a mood entry is necessary in order to be able to react to this. In the call center setting, based on preliminary design activities with a subset of target users, it was therefore decided to show the author of each mood entry. For the participants, the benefits of showing who had stated which mood, namely the possibility to react to statements of mood, outweighed the privacy concerns. Analysis of logged mood data showed a similar distribution of positive and negative mood entries, and we can therefore assume that users didn’t enter biased moods. Post-hoc, study results also showed that users were particularly interested in the mood entries of others, and we interpret results as this having increased overall user motivation to use the MoodMap App in the call-center setting.

**Synthesis**

The issue of data sensitivity and confidentiality in data-driven technologies for reflective learning is certainly relevant in all learning settings. On the other hand, it has not appeared as major concern in non-workplace related publications, while it has been mentioned in by Kocielnik et al. (2018b) as reason for implementing a study within the research team rather than in a third-party organisation.

One interpretation is, that in workplaces the issue is made complex by the fact that individual knowledge workers may feel (and often rightly so) not to have the power to decide the issue on their own. Starting an organisational decision-making process on the other hand may not be warranted given that the benefit of collecting and using data for learning is only potential, and is not be easy to causally relate to work performance. In addition, not every knowledge worker may have the organisational standing to start such a process. We also observe that sensitivity and confidentiality were a significant issue in designing the activity log based research prototype for time management, but were not the two studies based on collaborative mood self-tracking. There are two aspects in which these two research streams differed and which we believe made all the difference: Firstly, the activity log data were captured automatically. Study participants therefore didn’t control which data were logged or not, while in the mood self-tracking application all data were entered manually and hence under immediate user control. In addition, and partly as consequence of that, the data tracked with the mood self-tracking application only concerned the individual call takers, and mostly didn’t make (identifiable) statements about customers or about issues of organisational confidentiality.

From this discussion we draw out the understanding that self-tracked data, which allow for higher user control about data, and data that contain mostly information about the reflective practitioners (as opposed to information about clients, customers, or organisational procedures) make acceptance of technologies for data-driven technologies easier in terms of considerations on data sensitivity. On the other hand, this of course needs to be balanced with the need of captured data to represent relevant aspects of the object of reflection, and to be contextualised with respect to work practice.
6.3 Time and Space to Reflect

Designing for Time and Space

Overall, our studies underline the necessity of mapping out time and space for reflection as part of the socio-technical design process, and to include time and space considerations in the resulting socio-technical intervention. In all workplaces in which the present research is situated, time was perceived to be highly constrained by knowledge workers, even though continuous learning and also reflection in particular were explicitly understood to be relevant to work by knowledge workers. In all research streams therefore, it was a key concern to design the interventions such that they wouldn’t unduly disrupt operative work, and embed well with overall work practice. On the other hand, reflection simply cannot be done in no time at all. There is therefore a tension between time pressure in workplaces and time to reflect, which, of course, cannot be completely resolved. Results on that from own and others’ work are that experience mitigates this pressure, such that more experienced knowledge workers perceive time not as much as a barrier to reflection as less experienced colleagues (Renner et al., 2019OWN). Additionally, three observations from past work that serve as working assumptions for future research based are that i) time is more easily set aside for reflection when users have already set aside time for learning, e.g., in parallel to formal training; ii) scheduled reflection sessions tend to be longer but more infrequent than unscheduled reflection sessions; and iii) that scheduled reflection sessions with multiple reflection participants tend to be more strictly implemented as planned (e.g., coaching), whereas self-scheduled times for reflection tend to be shorter than planned. The latter has already been explained conceptually in relationship to theories of social norms and obligations (Pammer et al., 2015OWN), but not investigated systematically in the present work.

Secondly, it is also necessary to set aside space. In most studies reported in the present work, space was not a significant constraint. We did find however, that the lack of dedicated space for unobserved activity was a barrier for nurses to use the reflective quiz during their shifts, even if time were available. This is because work computers cannot be easily used for such personal use, and usage of personal smartphones was felt to project an unprofessional image (cp. Fessl et al., 2014OWN). Hence, space should be explicitly included in design considerations, even though in many cases space will be significantly easier to find than time.

Finally, there is the question of reflection as intervention versus reflection as practice. Reflection as intervention means, that reflection is intended to be done for a limited timespan by design; versus reflection as practice means that reflection is intended to be continually done as part of professional work practice. Neither is by itself good or bad; and either needs to suit the respective work practice and reflection object. The Medical Quiz including its reflection prompts was designed for reflection as intervention: Even if used outside the context of the qualification program, using the quiz and in parallel
to this engaging in reflection, are not part of the nurses’ everyday practice, and this is exactly as intended. The socio-technical intervention around KnowSelf could work both as intervention or as practice: Time management is certainly something that knowledge workers continuously do, however, equally certainly knowledge workers cannot continuously pay significant attention to how they do time management. Thereby, a longer-term pattern of reflection with respect to time management and usage of KnowSelf (or a similar tool) needs to be designed for reflection both as intervention and as practice. Beyond this, there is the possibility for a meta-practice such that time management is focussed on in an annual rhythm for instance, but every year as intervention (so a continual practice, with actions spaced widely in time). The MoodMap App on the other hand is suitable and has been designed for continuous use, in that ongoing usage takes very little time (only brief statements of mood and context) and offline follow-up is at the discretion of users. This has been enacted in the studied use case such that follow-ups with peers and managers were in direct response to concrete challenges within operative work.

**Automatic and Manual Tracking Induce Different Temporal Patterns**
The tension between time pressure from work and finding time to reflect was addressed differently at design time in the developed socio-technical interventions, and manifested differently at usage time in the field studies: In the activity-logging based interventions, automatic data collection was used to reduce the effort for data collection, and the basic activity logging tools mostly supported reflection-in-action. Adaptive reflection prompts that were pro-actively given to users in order to also incite reflection-in-action were found to be rather disruptive by study participants, and in the respective field studies, reflection-on-action at a self-chosen time was preferred. In both field studies, time to reflect on action had been explicitly set up i) at the end of each workday individually and ii) bilaterally on a weekly basis with a coach in one of the two studies. However, self-reported time of individual reflection-on-action was lower than the initially agreed upon timespans.

In the collaborative mood self-tracking intervention, mood needed to be explicitly and manually stated. This incited reflection-in-action in parallel to data capture. Indeed, in the call-center field study, reflection-in-action was the prevalent form of reflection, as indicated for instance by the low usage of reports (Rivera-Pelayo et al., 2017\textsuperscript{OWN}).

As overarching themes, the current understanding is therefore that manual tracking adds effort in using an application, but also invites to reflection-in-action. Reflection-in-action also helps in creating a representation of the momentary experience, as opposed to e.g., the remembered, retrospective experience (cp. Doherty & Doherty, 2018) as basis for reflection\textsuperscript{14}.

\textsuperscript{14} Of course, building up a retrospective account that potentially differs significantly from the momentary experience could be a sign for and outcome of reflection; the point above however is, that reflection-in-action may build up a data basis that is conceptually completely different from automatically logged data
When to Prompt?
In parallel, it is extremely challenging to time reflection prompts well. In very initial work (Stern et al., 2011\textsuperscript{OWN}), we tried to detect interruptibility of users when moving towards an appointment that is at a different physical location. The rationale was, that when people are on the way towards an appointment somewhere else and have sufficient time to reach the appointment, this might be a good time in between other activities in which to prompt. However, users varied extremely in their assessment of when a good time for proactive prompting would be. In subsequent work, other strategies were therefore followed. One strategy was to fix the timing of prompts in relationship to another activity. In the quiz for instance, reflection prompts (=reflection questions) were embedded in a learning activity; so setting aside the time for learning should not have been the problem. Nonetheless, reflection questions within the quiz were perceived as disruptive; albeit not disruptive to work practice but disruptive to game flow. A second strategy was to make timing only adaptive to content in the reflection tool (i.e. a prompt appears when content is identified as salient for reflection). For instance, in the case of KnowSelf, adaptive proactive prompts were shown in a few cases of salient activity log data (such as higher than average worktime fragmentation). A final strategy we explored was to allow users to self-set the timing according to fixed, regular times. However, both these strategies were found to be more disruptive than reflection guidance “on demand”, i.e. where users accessed reflection guidance functionality when they wanted. This is the major reason why in own current work on reflective search practice, reflection-in-action prompts are implemented as visual cues in a sidebar (Fessl, Wertner & Pammer-Schindler, 2018\textsuperscript{OWN}; Fessl, Pammer et al., 2017\textsuperscript{OWN}) that alert the user but don’t disrupt (cp. Fischer et al., 1993; p. 291).

6.4 Expectation Management: Small-R Reflection, Or: When is a Tool for Reflection Successful?
Schön (1983) understands reflection as continual and integral part of practice. Also in own empirical work, target users have understood reflection as integral part of their job (Pammer, Fessl et al., 2011\textsuperscript{OWN}). At the same time, we have noticed that that reflection doesn’t always lead to ground-breaking insights. The question therefore is: What are realistic expectations towards interventions designed for reflection in workplace settings? First the facts from own work: In own field studies, text fields that were intended to capture answers to reflection questions didn’t evidence reflection at all in the reflective quiz; 44,6% of notes in KnowSelf were of medium reflective depth and 18,4% were of high reflective depth; and 5,1% of notes in the field studies with the MoodMap app were of medium reflective depth and none of high reflective depth (Fessl, Wesiak et al., 2017\textsuperscript{OWN}, p. 8f).

\hspace{1cm} (which cannot constitute a representation of the reflective practitioner’s experience, just a representation of observable aspects of this experience); as well as completely different from reflection notes added temporally separated from the experience (reflection-on-action) as this will describe retrospective experience.
This need not be interpreted as reflection not having happened: In parallel, we always found that participants self-reported having reflected, and having generated plausible insights, in questionnaires, interviews, and group discussions. While self-reports are known to have limitations including imprecise memory of timespans and inaccurate attribution of causality, (cp. the design-oriented discussion in Doherty & Doherty, 2018), we have in interviews and group discussions always also asked for concrete exemplary insights. The underlying rationale mirrors the practice of contextual inquiry, to help users be as concrete and non-interpretative as possible in their accounts of practice (cp. Holtzblatt & Beyer, 2017).

The interpretation of a large number of notes in tools for reflection not being very reflective is three-fold: Firstly, not all reflection is documented within tools. In the collaborative mood tracking field study in call centers this was particularly visible, as collaborative mood tracking served mostly to trigger offline discussions amongst peers and with management (cp. Rivera-Pelayo et al., 2017OWN). These two factors that contribute to the low percentage of reflection notes are not the focus of the question of what can be expected from interventions designed for reflection, however.

It needs to be assumed that “in professional practice, a majority of reflection by necessity cannot lead to deep insights if the actor is indeed a professional” (Fessl, Wesiak et al, 2017OWN, p. 12). Indeed, it would be odd, if professionals continuously had fundamental insights about their work practice. Rather, it needs to be understood in workplace learning of professionals, that professionals in principle know their job, and are only fine-tuning their competence to deal with the natural uniqueness of the cases they work on (an inherent characteristic of knowledge work), as well as fundamental changes in the external world.

This doesn’t de-value reflection; quite on the contrary: It is this continual fine-tuning that can be assumed to be a core characteristic of knowledge work (cp. Kelloway & Barling, 2001). The authors understand knowledge work to be work in which finding, applying, creating and applying knowledge is essential to success. Further, by knowledge creation one needs to understand any activities that produce locally new knowledge, i.e. that knowledge which is new in a particular context. Similarly, by applying knowledge one needs to understand situations where the nature of knowledge is complex, adequate use of knowledge may be highly situational, and the problem itself may be wicked, in the sense of being unique, not allowing for repeated experimentation, and typically not offering any single correct solution (cp. Rittel & Webber, 1973). Reflection is one mechanism that contributes to such knowledge creation and application. In the context of creativity, Resnick (2007) has said that “little c (…) creativity – that is, creativity within one’s personal life – (isn’t) ‘big C’ creativity that transforms the boundaries of an entire discipline or domain” (ibid, p. 2). In parallel, I would like to coin the term “small r reflection” for ongoing reflective practice, as continual reflection within one’s personal or professional life, that doesn’t necessarily transform a person’s complete (personal or professional) life, that of one’s environment
(e.g., organisation), and even less that of an entire discipline or domain. Rather, small r reflection means to keep one’s eyes open towards small, necessary changes – thereby, overall significantly impacting all of the above. However, this perspective makes expectation management in practice, as well as in evaluating the effectiveness of an intervention in scientific studies challenging: One cannot simply count the number of insights gained, and behaviours changed. Therefore, I argue for a strongly qualitative approach towards measuring the success of an intervention designed for reflection. Firstly, the above understanding of small r reflection means, that it is the existence of reflective practice, as introduced by an intervention and accepted by study participants, including perceived usefulness of the intervention by study participants that is at the core of an evaluation, and indicates a well-designed intervention. Due to time pressure, it can be expected that professionals don’t engage in time-consuming practices out of kindness to researchers for a significant amount of time. Secondly, insights and changed behaviours need to be analyzed and weighted in a differentiated manner. On the one hand, it needs to be analyzed whether insights were reasonable and what was their perceived value in the environment in which the study is set. On the other hand, I argue that the level of experience of every single study participant needs to be very much taken into the account: Experts in their field are already reflective practitioners; otherwise they wouldn’t be experts. This however means, that it is hard to design an intervention that is perceived by experts as being of value, and enabling them to insights they wouldn’t be able to gain without the intervention. Therefore, if a knowledge worker gains a single, valuable insight through a multiple week intervention, this means the intervention was good; and this is truer, the more experienced the knowledge worker is.

6.5 What is Specific about Designing for Workplace Learning?

Finally, a question posed very much in the beginning of this work can be returned to: What is specific about workplace learning in the context of designing data-driven and adaptive technologies for reflection?

In the beginning of this work, the answer to this question emphasised that “the social context of work (…) defines the relevance of that which is learned” and that “the social context (of learning) is not designed for learning” (Section 2.2). All of the above themes for discussion contain elements that are specific to workplaces, and are not as visible in related work from educational and private life settings. Firstly, it has been observed above that in own work, data mostly represented aspects of a work-related object that is central to the respective organisation’s value-creating process. This is a logical consequence of investigating data-driven reflective learning in the workplace, where reflection objects that are important for learners to reflect on are aspects of work practice that benefit from reflection and are particularly valuable in the context of work. It also mirrors Littlejohn et al. (2012)’s findings that “learning goals (…) were linked to worktasks” (ibid, p. 229) in field studies that focussed on self-regulated learning. In addition, manually curated
artefacts were found to be valuable as complementing data in representing the reflection object. This can be assumed to be a particularly salient characteristic in workplace settings where professionals naturally reflect on aspects of work practice, and where this practice is complex and knowledge-intensive. Secondly, finding time for reflection as well as finding a suitable time, is challenging in workplaces due to the high time pressures of workplaces, and due to a typical prioritization of operative activities over learning. This prioritization has been observed next to the clear acknowledgement by study participants of the relevance of learning, reflective learning, and learning from experience (cp. Pammer, Fessl et al., 2011).

Thirdly, sensitivity and confidentiality of data has not appeared as salient issue in design-oriented literature in educational and private life settings; whereas it has always been a key element in discussions with users and relevant stakeholders in own work.

Beyond what has been discussed in detail in Sections 6.1-6.4 above, our studies have indicated repeatedly that reflection in workplaces is inherently social. This can be seen where reflection has been identified to involve multiple reflection cycles with varying reflection participants (Section 4.2); where systematic peer exchange was explicitly desired when it was missing (activity logging as basis for time management; Section 5.2) and in that triggering subsequent reflection cycles in the form of systematic peer and managerial support has been a major function of collaborative mood tracking (Section 5.3). Subsequently, this means that issues of power are concretely relevant, such that whose role and organisational power it is to change work practice and to implement insights gained through reflection is a core consideration for reflection participants, and need to play their part in design. Exemplary ways to acknowledge such issues in design are to support sharing of data and materials, and to respect different roles and organisational power in the design of practice around technical tools.
7 Outlook: From Data to Intelligent Mentoring

The very initial research vision of the present habilitation was to use data about work practice in a similar way that Runtastic or FitBit take data about physical activity, namely as basis for changing and improving work practice. Over the years, the vision of course changed. Very quickly, a central extension was to increasingly explore adaptive reflection guidance. A second central adaptation of this vision was to acknowledge that complex knowledge work, and knowledge about it, isn’t easily represented by automatically collected data. As a consequence, manual tracking and contextualisation components were increasingly included in designs. It has become apparent that the trade-offs between automatic and manual tracking need to be assumed to be complex, and to warrant further research: On the one hand, automatically logged data don’t require user effort during tracking. On the other hand, data can represent only a limited aspect of that which is relevant for reflection in knowledge-intensive work settings, whereas manual tracking needs time but immediately forces or encourages brief times for reflection.

I see the following as relevant research directions that follow immediately from the presented own work in combination with existing literature. One direction is to systematically explore the dichotomy of automatically logged and manually tracked data as basis for reflection in terms of patterns of engagement, generated insights, and resulting impact. Overall, design needs to consider the value of automatically collected data as providing factual and objective partial truths, and the value of manually curated artefacts to be able to account for the complexity of reality; and design needs to pay attention to allow reflection participants to generate varying, and changing representations of the reflection object.

Secondly, adaptive reflection guidance as a form of intelligent mentoring is its own huge field for research. A specific direction that I see as promising in this field, is to investigate prompts that are intelligent and interactive enough to understand to which curated learning materials a learner needs to be pointed to. The explanation of knowledge within the learning domain, or concrete advice on learning can remain encoded in manually curated learning materials. This approach is inspired by Baker (2016), who discusses that traditional intelligent tutoring systems that formally encode domain and didactical knowledge haven’t fared well in ill-structured domains; and by Dimitrova & Brna (2016) who discuss intelligent mentoring systems as promising direction for future research in artificial intelligence in education. However, my approach to artificial intelligence is significantly inspired by Rogers (2006)’ call to focus on making humans intelligent, e.g. by emphasizing interactivity, rather than on making systems intelligent.
Appendix A  Commented List of Own Publications

The above habilitation text synthesizes research which has been published in peer-reviewed venues in a cumulative manner. The list below gives references, and indicates my role and contribution in publications with multiple authors. Below the list of peer-reviewed publications, edited works and book chapters related to the habilitation are listed for further completeness. Note that it was usual practice in my environment to give first authorship to the involved student, irrespective of the student’s seniority.

A.1 Own Publications

This appendix mainly lists peer-reviewed publications that constitute the present habilitation.

J = Journal article (6)
P = Conference paper (8)
WiP = Works-in-Progress, Poster, Demo, Late-Breaking Works, Workshop Papers (12)

Two non-peer reviewed publications are included in the list below. The book chapter (number 2) summarizes one of the research streams (Fessl, Wesiak & Pammer-Schindler, 2018). The technical report (number 28) details empirical foundations for design and theoretical work that is part of this habilitation (Pammer, Fessl et al., 2011).

B = Book chapter (non peer-reviewed, 1)
T = Technical report (non peer-reviewed, 1)

Habilitation guidelines require that multiple author papers are commented in order to clarify own contribution to the paper. This is done in italics below each single reference.

1. (J) Bettina Renner, Gudrun Wesiak, Viktoria Pammer-Schindler, Michael Prilla, Lars Müller, Dalia Morosini, Simone Mora, Nils Faltin & Ulrike Cress. Computer-supported reflective learning: How apps can foster reflection at work. Behaviour & Information Technology, Taylor & Francis, 2019. DOI: https://doi.org/10.1080/0144929X.2019.1595726 I contributed empirical research, to literature research, as well as to paper-writing in all iterations of writings as I had the honor and pleasure to be part of the core writing team (first three authors and last author).

I contributed to technology and study design, and to paper-writing. The chapter is based on Angela Fessl’s PhD, for which I was co-supervisor.

I contributed to the original idea, to the elaboration of the prototype, and to paper-writing.

I co-supervised Angela Fessl’s PhD, and contributed throughout the research presented in this journal paper to literature research, conceptualization of socio-technical interventions, evaluation methodology, and to paper-writing.

I contributed to the conceptualization of mood tracking as socio-technical intervention for reflection, to literature research, evaluation methodology, and paper-writing.

I led the discussions and paper-writing. This paper is the synthesis and reflection on a series of papers by the same authors in which we developed terminology and a model of computer-supported reflection in the workplace from multiple perspectives. All authors have contributed significantly to the joint work.

I contributed to the conceptual work, i.e. categorization of papers (the paper is a literature review) and paper-writing.

I contributed to the concept and design of the interventions that were discussed in the focus group, to literature research and paper-writing.

I co-supervised Angela Fessl’s PhD, and contributed to the original idea of using reflection prompts within a quiz environment, to the study design of empirical work, to literature research, further conceptualization of the socio-technical intervention, and to paper-writing.

I contributed to the original idea of exploring a configurable visualization application in the context of reflecting on data, to study design, and to paper-writing.

I co-supervised Angela Fessl’s PhD, and contributed throughout the research presented in this journal paper to literature research, conceptualization of socio-technical interventions, evaluation methodology, and to paper-writing.

I led the design of the evaluated socio-technical intervention, contributed to the method of evaluation, led literature research and paper writing, and contributed to the analysis of data.

I conceptualized multiple roles of mood-tracking and mood-based
reflection in relationship to public spaces, based on own empirical work and literature research.

I co-supervised Angela Fessl’s PhD, and contributed to the original idea of using reflection prompts within a quiz environment, to empirical work, to literature research, further conceptualization of the socio-technical intervention, and to paper-writing.

I contributed to the paper idea, led discussions and led paper-writing. The paper is theoretical but parts of the security concept have been implemented. Background in security analysis came from Roderick Bloem’s group.

I contributed to the discussions, literature research, and paper-writing. This is one of a series of papers by the same authors in which we developed terminology and a model of computer-supported reflection in the workplace from multiple perspectives. All authors contributed significantly to this work.

I contributed to the discussions, literature research, and paper-writing. This is one of a series of papers by the same authors in which we developed terminology and a model of computer-supported reflection in the workplace from multiple perspectives. All authors contributed significantly to this work.

I contributed the idea of activity logging as basis for reflection on time
management, and of visualizing the fragmentation of knowledge work. I led the study design and carried out empirical work. I also led paper-writing and literature research.

I contributed to the discussions, literature research, and paper-writing. The paper discusses the multiple roles of technology in reflection.

I contributed empirical data, to concepts discussed in the paper, literature research, and to paper-writing; especially contributing the different directions of reflective communication (push and pull) and the concept of lost learning opportunities. All authors contributed significantly to this work.

I co-supervised Angela Fessl’s PhD, and contributed to the conceptualization of the mood tracking application, and to paper discussions and writing.

22. (WiP) Viktoria Pammer, Stefan Edler, Hermann Stern. Visualising the Fragmentation of Knowledge Work. Nordic Conference on Human-Computer Interaction, NordiCHI ’12, Copenhagen, Denmark, October 14-17, 2012.
I contributed the idea of activity logging as basis for reflection on time management, and of visualizing the fragmentation of knowledge work. I also led paper-writing and literature research.

I designed the paper concept and led the discussions (the paper is conceptual, based on theory and empirical work) and paper-writing.

MobiQuitous 2011. December 6-8, Copenhagen, Denmark, 2011.

I contributed to conceptualization, study design, literature research, and paper-writing.

I led the discussions (the paper is conceptual) and paper-writing, and contributed to literature research.

I co-supervised Angela Fessl’s PhD, contributed to the conceptualization of the mood tracking application, to empirical work, and to paper discussions and writing.

I contributed to discussions (the paper is conceptual, and paper-writing.

I led data analysis and writing of the report.

A.2 Editorial Work

For completeness, I also list editorial work I have done in the field of technologies for reflective learning.

E = Editorial work

I contributed as co-editor to the special issue, including call for papers, monitoring the review process, and editorial writing.
   I was co-organiser of the workshop, and co-editor of the proceedings.

   I was co-organiser of the workshop, and co-editor of the proceedings.

   I was co-organiser of the workshop, and co-editor of the proceedings.

   I was co-organiser of the workshop, and co-editor of the proceedings.

   I was co-organiser of the workshop, and co-editor of the proceedings.

   I was co-organiser of the workshop, and co-editor of the proceedings.

   I was co-organiser of the workshop, and co-editor of the proceedings.
Appendix B  References

The below are references of other researchers used in the above habilitation.


68. Morris, M.E., Kathawala, Q., Leen, T.K., Gorenstein, E.E., Guilak, F., Labhard, M., and Deleeuw, M. Mobile therapy: Case study evaluations
of a cell phone application for emotional self-awareness. Journal of Medical Internet Research, 2010, Vol. 12, No 2. DOI: https://doi.org/10.2196/jmir.1371


82. Rogers, Y. Moving on from Weiser’s Vision of Calm Computing: Engaging Ubicomp Experiences. Proceedings of the 8th International


