Communications of the Association for Information Systems

Volume 52 Paper in press

April 2023

Managing the Inner Workings of Collective Intelligence Approaches for Wicked Problems – An Assessment Model and Evaluation

Henner Gimpel
University of Hohenheim, Stuttgart, and FIM Research Center, Project Group Business & Information Systems Engineering of the Fraunhofer FIT, Augsburg, henner.gimpel@uni-hohenheim.de

Robert Laubacher
Center for Collective Intelligence, Massachusetts Institute of Technology, USA

Dominik Parak
University of Augsburg, Germany

Manfred Schoch
University of Hohenheim, Germany, FIM Research Center for Information Management, Fraunhofer Institute for Applied Information Technology FIT, Branch Business & Information Systems Engineering

Moritz Wöhl
University of Augsburg, Germany, FIM Research Center for Information Management, Fraunhofer Institute for Applied Information Technology FIT, Branch Business & Information Systems Engineering

Communications of the Association for Information Systems

Accepted Manuscript

Managing the Inner Workings of Collective Intelligence Approaches for Wicked Problems – An Assessment Model and Evaluation

Henner Gimpel
University of Hohenheim, Germany,
FIM Research Center for Information Management,
Fraunhofer Institute for Applied Information Technology FIT, Branch Business & Information Systems Engineering
henner.gimpel@uni-hohenheim.de

Robert Laubacher
Center for Collective Intelligence
Massachusetts Institute of Technology, USA

Dominik Parak
University of Augsburg
Germany

Manfred Schoch
University of Hohenheim, Germany,
FIM Research Center for Information Management,
Fraunhofer Institute for Applied Information Technology FIT, Branch Business & Information Systems Engineering

Moritz Wöhl
University of Augsburg, Germany,
FIM Research Center for Information Management,
Fraunhofer Institute for Applied Information Technology FIT, Branch Business & Information Systems Engineering

Please cite this article as: Gimpel, H., Laubacher, R., Parak, D., Schoch, M., & Wöhl, M. (in press). Managing the inner workings of collective intelligence approaches for wicked problems – An assessment model and evaluation. *Communications of the Association for Information Systems.*

Communications of the Association for Information Systems

Research Paper ISSN: 1529-3181

Managing the Inner Workings of Collective Intelligence Approaches for Wicked Problems – An Assessment Model and Evaluation

Henner Gimpel

University of Hohenheim, Germany,
FIM Research Center for Information Management,
Fraunhofer Institute for Applied Information Technology FIT, Branch Business & Information Systems Engineering
henner.gimpel@uni-hohenheim.de

Robert Laubacher

Center for Collective Intelligence
Massachusetts Institute of Technology, USA

Dominik Parak

University of Augsburg
Germany

Manfred Schoch

University of Hohenheim, Germany,
FIM Research Center for Information Management,
Fraunhofer Institute for Applied Information Technology FIT, Branch Business & Information Systems Engineering

Moritz Wöhl

University of Augsburg, Germany,
FIM Research Center for Information Management,
Fraunhofer Institute for Applied Information Technology FIT, Branch Business & Information Systems Engineering

Abstract:

Ill-defined and complex problems that affect multiple stakeholders with potentially conflicting perspectives are often referred to as wicked problems. The utilization of collective intelligence (CI) via web-based platforms is a promising approach for addressing such wicked problems. The management of these information systems would benefit from evidence-based decision support regarding facilitation and improvement efforts. However, to date, there is no suitable model to guide such efforts. Existing approaches address specific applications or cover certain assessment areas but do not provide a holistic perspective. Meanwhile, research offers substantial insights into best practices for addressing wicked problems and running CI applications. This paper develops an assessment model comprising five central success dimensions for information systems that address wicked problems. Their subdimensions and associated measurement metrics allow for evidence-driven facilitation and improvement of CI applications for wicked problems. Apart from the model's capability to improve future runs and processes, it also offers the potential to provide immediate insights for facilitation efforts during runtime. The model was validated with a platform dealing with the assessment of risks presented by global climate change. This evaluation generated strong evidence for the model's applicability and usefulness.

Keywords: Assessment Model, Collective Intelligence, Crowdsourcing, Mass Collaboration, Decision-Support, Wicked Problems.

1 Introduction

Wicked problems include some of humanity's most relevant and pressing challenges, such as climate change (Levin et al. 2012) and peace settlements (Head 2008). The term *wicked problem* was coined by Horst W. J. Rittel and described a "class of social system problems which are ill-formulated, where the information is confusing, where there are many clients and decision-makers with conflicting values, and where ramifications in the whole system are thoroughly confusing" (Churchmann 1967, p. 141, p. 141). Due to the potential divergence in values, viewpoints, and expertise held by the different stakeholders, collaborative strategies are recommended to leverage the CI of all stakeholders (Roberts 2000; Roberts 2002). In earlier days, collaboration among stakeholders was primarily possible in face-to-face meetings; the rise of information technology allows for addressing wicked problems via mass collaboration (Potter et al. 2010; Ye and Kankanhalli 2013). The approach of combining the use of both humans and machines in this process is said to have the potential to tackle some of the most wicked problems (Michelucci and Dickinson 2016). Over time more and more web-based platforms have specifically been built to deal with wicked problems.

A subgroup of such systems is CI applications for wicked problems, which are socio-technical information systems (IS) that combine contributions by humans who interact via IT platforms and are guided by defined processes to leverage CI. To encourage individuals to participate and collaborate actively, facilitation of the process is typically necessary. Facilitation can include fostering communication among individuals via the underlying IT platform, encouraging interaction by making the formation of teams part of the process, and actively selecting the crowd of individuals. Consequently, the platform owners and facilitators of CI applications for wicked problems have multiple opportunities to influence its outcome. Their work is crucial in conceptualizing the platform and the process, facilitating and running the process during runtime, and redesigning the platform for subsequent use. For all these activities, it is essential to understand the process, structure, and collaboration on the platform and derive actions from those insights to make necessary adjustments. The literature currently lacks a holistic model for platform owners and process facilitators to assess their CI applications for wicked problems. Existing literature only addresses specific aspects of such applications or focuses on the analysis of a single case example. It may thus not be transferable to a broader range of applications.

A simple use case might illustrate the problem and relevance: The *ClimateRisks CoLab* (CRC) is an online scenario planning exercise to explore how climate variability and change may impact human security risks over the coming years. It brings together experts with high disciplinary and regional diversity to collaborate through an online platform towards collectively intelligent solutions for wicked problems in the climate risks domain. The platform owners and the facilitators supporting the experts in their collaboration face the problem of not knowing what good facilitation of such a process looks like and which aspects need to be considered. Good facilitation is not an end to itself but ultimately helps to find good solutions to wicked problems.

However, measuring the success of solutions to wicked problems is difficult. Likewise, assessing ideas regarding potential solutions proposed through IT platforms is difficult. This difficulty is because effects often take very long to become visible, and it is very challenging to isolate the impact of a single intervention when considering the vast number of areas in which interventions occur (Ketter et al. 2015). Quality criteria for *good* interventions are thus non-existent (Ketter et al. 2015; Pries-Heje and Baskerville 2008). Pacanowsky (1995, p. 37, p. 37) adds to this narrative by stating that "we do not really 'solve' wicked problems; rather, we 'design' more or less effective solutions." The associated solution design process is iterative, with adaptive management being a key factor for success (Zijp et al. 2016). In an article on the role of IS for wicked problems, Schoder et al. (2014, p. 5) consequently point to the adage "the better we measure, the better we manage" and state that the issue of measurement is an important area for research. Associated with management, there is an old saying going back to both W. Edward Deming and Peter Drucker, stating that "You can't manage what you don't measure." In online communities and communities of practice, the community's facilitation and management play an important role (Johnson 2001). As laid out, this is also the case for the management of IS, specifically online platforms, used for designing solutions for wicked problems (Schoder et al. 2014; Zijp et al. 2016). Therefore, we propose that adequate decision support for such CI platforms' process and structure for wicked-problem-solving is essential for their success.

Thus, two interrelated challenges arise for platform owners and facilitators: 1) not truly knowing whether a solution is good and thus having to rely on a good solution design process to increase the quality of the produced ideas, and 2) lacking operational metrics before, during, and after the participant collaboration to facilitate the process effectively. The situation can be summarized in a problem statement: Platform owners and facilitators of CI endeavors for solving wicked problems have challenges in managing the platforms and processes as they lack tools for assessing the quality of the structure, process, and solution. To this problem, we posit the following purpose and scope of our research:

> ***Support owners and facilitators of collective intelligence platforms for solving wicked problems in their decision-making to ensure solution quality.***

Regarding the process, platform owners and facilitators have individual expertise and intuitions of what high quality looks like, but they lack support in managerial and IT tools. At the same time, the possibilities to measure and assess these solution design processes have greatly increased with the advent of online platforms and the abundant availability of digital trace data that allows for analysis of the process and the stakeholder interaction.

However, to date, we lack knowledge of what to look for in the process to understand the quality. To address this problem, we propose a model for assessing such endeavors based on three things: best practices for dealing with wicked problems, the analysis of multiple CI applications for wicked problems, and an extensive review of existing literature. The derived model enables a structured assessment of success dimensions by deriving quantitative metrics essential to understanding how well CI platforms for addressing wicked problems work. We evaluate the model's applicability and usefulness by applying it to a real-world CI endeavor.

2 Conceptual Background

2.1 Wicked Problems

Even though multiple, slightly different definitions of the term wicked problem have evolved over the years, the ten properties originally outlined by Rittel (1972) and Rittel and Webber (1973) still guide the understanding of wicked problems. Wicked problems are problems, which are highly complex, uncertain, and the important stakeholders have divergent and fragmented viewpoints, values, and intentions for them (Head 2008). This characterization means that extreme complexity alone does not make a problem a wicked problem, nor does high uncertainty or disagreement among stakeholders. Only the combination of these characteristics constitutes a wicked problem.

Because of the importance of wicked problems, approaches for dealing with them have received considerable attention. Roberts (2000; 2002) introduces three general strategies for dealing with wicked problems – authoritative, competitive, and collaborative. An authoritative strategy can be applied to tame a wicked problem if power is not dispersed and a group of people (e.g., experts, executives, or a legislative body) can control the decision process. This way, the problem is tamed by substantially reducing the divergence and fragmentation of viewpoints by limiting and selecting involved stakeholders. A competitive strategy might be observed if the power over a decision or situation is contested like it is often the case in zero-sum games. Examples of competitive strategies to address wicked problems can be seen in competitive markets (e.g., the race towards developing new technology), politics, and the military. Collaborative strategies, however, are grounded in a win-win perspective of jointly achieving more than what would be possible individually. As wicked problems are socially defined, bringing together different stakeholders to learn from each other and collaborate is often suitable. The collaborative strategy is also heavily supported by literature, and its influence can be observed in numerous approaches to dealing with wicked problems (Roberts 2000; Roberts 2002; Tatham and Houghton 2011).

2.2 Collective Intelligence

At the core of such collaborative strategies lies bringing together different stakeholders to exchange their opinions and work together. There, wicked problems research intersects with CI research. While many different definitions of CI exist (c.f. Malone 2015 for an extensive list), we refer to a broad one here: "groups of individuals acting collectively in ways that seem intelligent" (Malone et al. 2010; Gimpel 2015). Studies have found evidence for a CI factor that represents a group's general ability to perform well on a wide variety of tasks (Woolley et al. 2010). This factor is said to depend on elements such as the composition of the group and the way the group interacts and collaborates. Other studies indicate that CI approaches can mitigate biases in decision-making in many different areas of application, both in the generation of potential solutions and the evaluation of these solutions (Bonabeau 2009). In that regard, the crowd can be particularly helpful when resources associated with the activities are distributed widely, the activities to be performed can be divided into pieces, and the relevant information can be shared (Malone et al. 2010).

There are two different ways in which individuals can work together to create ideas. More extensive activities that can be broken down into smaller independent pieces and addressed by different individuals separately are called *collections*. In contrast, when the pieces are interconnected so that they cannot be divided into independent pieces, *collaboration* amongst the group is necessary. As laid out, wicked problems are complex, thus generally falling into the latter category and requiring extensive collaboration. For collaboration, dependencies must be managed (Malone et al. 2010).

CI research has seen a stark increase in the past decades as new CI forms have emerged thanks to the widespread availability of information technology (Malone 2015). Thus, the proposed basic definition has been extended to reflect the technological elements: "interconnected groups of people and computers doing intelligent things" (Malone 2015, p. 1). Not only does the crowd interact with computers, but also the collaboration across human actors can now be greatly facilitated through the usage of technology. For example, people from different geographical locations can now connect through the internet and collaborate remotely through new types of IS, such as social software and other collaboration technologies. Based on such technologies, multitudes of CI platforms have tried to tackle different kinds of problems. We proceed to give an overview of such existing CI communities at the intersection with wicked problems.

2.3 Collective Intelligence Communities

Looking at today's wicked problems like climate change, the geographic reach, and the quantity and divergence in opinions are extreme. Modern technologies provide a way to overcome these barriers and enable mass collaboration (Potter et al. 2010; Ye and Kankanhalli 2013). Engineering the corresponding large-scale CI applications is a major research challenge for the IS discipline (Schoder et al. 2014).

One example is MIT's Climate CoLab (Introne et al. 2013; Malone et al. 2017), which tries to tackle global climate change with its community of over 100,000 people from all around the world. The process is based on participants developing proposals in online contests that outline actions that might be taken in specific realms (e.g., increasing building efficiency or decarbonizing electricity production). After the submission of proposals, a recruited panel of experts reviews them and selects semi-finalists. The selected participants then revise their submissions, and the judges select the finalists. Afterward, the judges select the winner of the Judges' Choice Award, and the community selects the winner of the Popular Choice Award. In addition to running contests in specific domains, the Climate CoLab has also used contest webs, in which integrated proposals are sought that combine entries from earlier contests (Malone et al. 2017).

Similarly, the collaborative design network OpenIDEO hosts crowdsolving contests. Participants aim to solve an outlined challenge via a five-phase process, which involves initial research, the contribution of ideas, the refinement of ideas, the provision of feedback, and the evaluation of top ideas. Participants can post and respond to comments on concepts during the entire process, fostering further social interaction (Fuge et al. 2014; Bianchi et al. 2015). Other examples include a broad portfolio of applications, such as the YouCity Challenge, PARCEL, and CrowdForge.

While the introduced CI applications for wicked problems are all quite different, they share the principle of guiding diverse participants along a structured problem-solving process. This process often uses similar essential elements to leverage CI, such as creating initial ideas and the subsequent combination and refinement into more elaborate constructs and likely some evaluation (e. g., through voting).

2.4 Related Work on Implicitly Measuring Quality

Efforts on CI platforms primarily aim at identifying high-quality contributions that help to tackle the problem in focus. Idea quality, however, is not observable ex-ante. For example, Kornish and Ulrich (2014) identify that the true quality of raw ideas in innovation is only theoretical, as it cannot be observed directly but only indirectly – for example, through expert panels or consumer surveys. In their work, they aggregate multiple dimensions of quality. To evaluate the ideas' quality, they use a small sample of products that make it to the market. The solutions generated through collaboration activities in online platforms for wicked problems, such as the scale of climate change risks, take much longer to take effect, and tracing their impact back to a single measure is virtually impossible. Thus, we need other measures to approximate success.

Dating back to 1966, Donabedian describes service quality assessment in health care. Similar to the problem at hand, health care quality is difficult to assess due to the time it takes for actions to manifest themselves in outcomes. Donabedian (1966) thus develops a model that suggests the *structure* and *process* of medical treatment as relevant factors to determine service quality.

More closely related to CI, Durward et al. (2016) propose an ideal-typical process of crowd work projects, including phases such as the specification of the task, selection of workers, tasks processing, and aggregation and selection of the most appropriate solutions. While this provides a good starting point for analysis, wicked problems' unique nature requires a stronger emphasis on collaboration rather than collection (Malone et al. 2010). Furthermore, the measures potentially relevant to the management of such an online platform to develop solutions remain to be identified. Elia and Margherita (2018) develop a holistic conceptual framework for the study of wicked problem-solving processes from problem identification to solution maintenance. Their paper also suggests activities to propose and assess solutions to wicked problems in a structured way while emphasizing the importance of CI. They suggest the definition of performance indicators and the assessment of solutions.

The related literature shows that many researchers have addressed quality assessment in associated fields, and others have measured particular aspects of CI systems used to address complex problems. However, to the best of our knowledge, no model exists that provides a holistic view of the assessment of CI platforms geared towards developing solutions for wicked problems. Thus, we built on the existing literature by integrating knowledge from the different approaches and perspectives into one holistic model.

3 Methodology

The present study follows the design science research paradigm (Hevner et al. 2004; Peffers et al. 2007; Gregor and Hevner 2013). Design is a search process (Hevner et al. 2004). We are guided by the nominal process of Peffers et al. (2007), taking the objective-centered solution variant triggered by practitioners' needs. The design process leads to prescriptive knowledge (Sonnenberg and vom Brocke 2012; Hevner et al. 2019). Our design artifact is a model (Hevner et al. 2004; Gregor and Hevner 2013; March and Smith 1995) to assess CI applications for solving wicked problems.

Following the classification of theories in IS as suggested by Gregor (2006), we contribute to a theory for design and action (type V). Our model can be classified as a level 2 nascent design theory, which produces knowledge as operational principles (Gregor and Hevner 2013). Instantiations of this abstract design artifact shall support platform owners and facilitators, thereby contributing to higher-quality solutions to wicked problems. Importantly, we do not claim to provide a well-developed level 3 mid-range or even grand design theory (Gregor and Hevner 2013) – this is yet to emerge from maturing and generalizing design knowledge.

The validity of design science research results can be assessed through descriptive knowledge obtained in the design science research process. In search of a satisfactory design, evaluation against descriptive knowledge plays a vital role. For such a continuous evaluation of our assessment model, we follow the four evaluation phases that Sonnenberg and vom Brocke (2012) suggest in a design-evaluate-construct-evaluate pattern. The phases *identify problem*, *design*, *construct*, and *use* build the artifact; *Eval 1* to *4* evaluate it in successive steps (c.f. Appendix). The evaluation criteria follow the suggestions by March and Smith (1995) and Sonnenberg and vom Brocke (2012) for model artifacts. All four evaluation episodes leverage the CRC as an exemplar of a CI platform for addressing wicked problems.

4 Case Setting for Multiple Evaluation Episodes: CRC

CRC was developed by the Center for Collective Intelligence of the Massachusetts Institute of Technology, in cooperation with the Skoll Global Threats Fund (a non-profit fund dedicated to addressing global threats) and Future Earth (a multi-national non-profit organization dedicated to sustainable development). It provides an online platform that aims to bridge sectoral and regional silos by bringing together different experts worldwide to explore how climate variability and change may affect human security risks over the next three to five years.

The CRC platform and process aim to encourage a diverse set of participants to work together and develop integrated contributions that outline under-recognized future climate risks. A five-phase process was enacted with a sequential flow and time-based transitions between the phases (*Figure 1*).

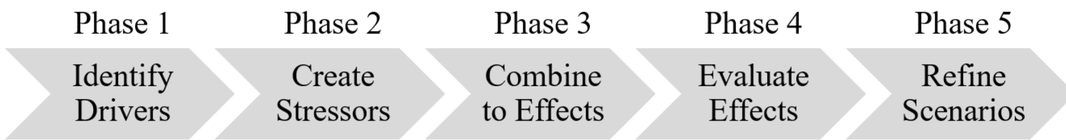

Figure 1. Five Micro-Phases of CRC CI Exercise for Wicked Problems

In the first two phases, participants identify non-environmental drivers and environmental stressors of climate change that may impact the world (or a single sector or region) over the next three to five years. Afterward, participants are encouraged to work in small groups to combine multiple non-environmental drivers and environmental stressors to identify potential mutually reinforcing/cascading effects on human security. In Phase 4, all participants vote on which effects are most novel, meaningful, and worthwhile to explore further. Finally, in Phase 5, teams are formed, and participants are invited by the process facilitators to collectively explore sets of the top-voted effects to form detailed scenarios.

A pilot run of this process was executed with a total of 87 experts participating. The results (see Skoll Global Threats Fund 2017) were presented at Planetary Security Conference, and a trimmed-down version was run offline during the conference. Two subsequent runs with modification of platform, process, and specific wicked problem addressed were run subsequently. While these previous runs are informed by the design science research project presented here (details follow below), this study's primary focus is on the pilot run.

5 Problem identification and justification

We identified the problem of assessing CI endeavors' quality for solving wicked problems in in-depth expert interviews with both an owner and a facilitator of a CI platform. Given the interviewees' experience from the CRC, their own experience with multiple other CI approaches, and their exchange with platform owners and facilitators of other CI approaches, we rely on them to formulate the problem statement, research gap, and design purpose and scope. The specific problems, a use case exemplar, and the design purpose and scope were presented in section 1. To justify the importance and novelty of the problem, we used a literature review and further expert interviews (Eval 1 from Sonnenberg and vom Brocke 2012). In aggregate, these perspectives support the problem's importance and lack of a solution. The purpose and scope of a solution are to assess the quality of the specific structure and process of a CI endeavor as a proxy for solution quality.

Further, we pursued semi-structured expert interviews with the platform owner and facilitator. The interviewees reported that an assessment of structure and process is necessary for multiple phases of the endeavor (*Figure 2*). It is important to know how people interact on the platform to moderate and facilitate adequately during the process. We call this the *runtime phase*. Examining the run retrospectively in order to digest the results and learn from them is also important. We call this the *post-phase*. Insights in this phase inform changes for the next run. Under the assumption that a platform is built to be reused, we call this the *redesign phase*. Afterward, the recruiting and preparation start again, which can be called the *pre-phase*.

Along with these phases, the platform owner owns and operates the web-based platform for the experts to engage. The platform consists of IT components and build-in process, interaction, information processing, and displaying components. The facilitator supports the platform by providing assistance, guidance, and supervision to the CI endeavor's sponsor and the crowd.

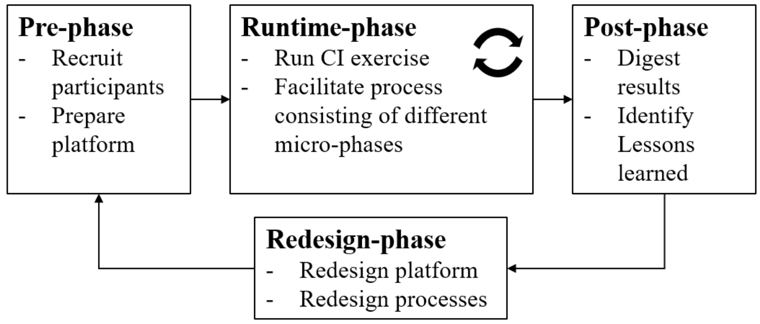

Figure 2. Macro-Phases of a Collective Intelligence Platform for Wicked Problems Solving

The platform owners and facilitators are interested in informing their decisions in all four phases through a structured assessment model rather than using anecdotal insights and subjective perceptions to inform changes to their platform and processes.

6 Design and Demonstration

To identify the success dimensions for wicked-problem-solving, we examine the existing literature. We used the search query "wicked problem" in three scholarly databases: AIS eLibrary, IEEE Xplore, and ScienceDirect. Also, we applied the query "'wicked problem' AND 'collective intelligence'" to Web of Science. Subsequently, we evaluated the results for relevance and identified papers that include statements on dealing with wicked problems (e.g., advice or best practices). We only considered aspects related to crowds and their activities, not those that address policy topics or similar issues. We refined the sampling through a forward and backward search based on the resulting list of relevant articles. We identified a total of 39 papers, from which we extracted 71 statements indicating possible success dimensions of how wicked problems can be addressed. An exemplary statement: "When it comes to approaching wicked problems we need to think about a resolution rather than a solution and a consensus rather than optimization" (Eldabi 2009, p. 1835). See Online-Appendix[1] for a list of all 39 papers and 71 statements.

One of the authors coded the statements using open coding as suggested by Strauss and Corbin (1990). Three of the authors identified overarching categories (e.g., participants or content) through axial coding, which resulted in five such categories. All decisions were made in consensus. Lastly, a fourth author double-checked all statements and checked for consistency in the coding. The example statement mentioned above was categorized as "Collective Learning."

The final model consists of five categories with fifteen subcategories, which address different aspects or levels of CI applications for wicked-problem-solving. *Figure 3* illustrates the five success dimensions (Participants, Activities, Content, Collective Learning, and Iteration), their connections, and their respective subdimensions. Our example statement was matched to the subcategory "Convergence."

Through the depicted process, solutions to wicked problems are developed, and consensus is reached, which may or may not lead to actions tackling the problems. Besides that, it is understood that the entire process and its iterations need an initiation. Further, when participants have created good solutions, they need to be put into action. We include these steps in our model but do not make them subdimensions of our assessment model since our focus lies on assessing the process and the platform to derive actions from improving them. The subdimensions and the two additional steps are depicted in *Figure 3*. We proceed to present the five success dimensions.

[1] https://ln5.sync.com/dl/04618ada0#ffu7utzy-cjbxizkx-rq32pwaz-7jbu6ynr

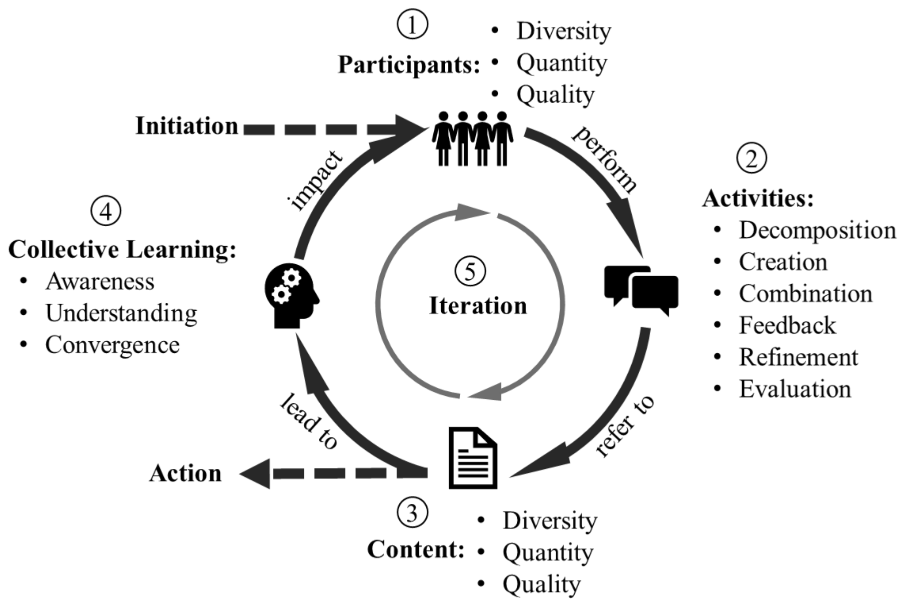

Figure 3. Model of Success Dimensions for Addressing Wicked Problems by Information Systems that Harness Collective Intelligence

6.1 Participants

Many of the statements we identified in the literature address the importance of the participants involved. Early on, Rittel (1972, p. 394) argued that "the expertise which you need in dealing with wicked problems is usually distributed over many people." Subsequently, many authors state the importance of stakeholder and participant ***diversity*** (Conklin 2006; Raisio 2009; Davies et al. 2015; Head and Alford 2015; Ketter et al. 2015; Innes and Booher 2016; Brunswicker et al. 2017) and team diversity (Introne et al. 2013; Edzen 2014). The Australian Public Service Commission (2018) and Roberts (2000; 2002) go one step further and state that *stakeholder completeness* is desirable. Besides, it is important to note that stakeholders involve people actually affected by the wicked problem in question, rather than solely experts (Rittel 1972; Brunswicker et al. 2017). In addition, and particularly important for global problems, such as climate change, *geographical diversity* is suggested (e.g., Introne et al. 2013).

Further, the process of addressing wicked problems should be interdisciplinary (Sharts-Hopko 2013; Alrøe and Noe 2014; Duckett et al. 2016; Fleming and Howden 2016) and transdisciplinary (Sharts-Hopko 2013; Xiang 2013; Duckett et al. 2016; Fleming and Howden 2016; Head and Xiang 2016; Head et al. 2016) by nature. We subsume this as *expertise diversity*. Other authors also argue for ideological diversity, which might help gain widespread acceptance for the proposed solutions (Rittel and Webber 1973; Davies et al. 2015).

During our iterative design process, we added *gender diversity* as a self-developed factor. It seems intuitive in terms of stakeholder completeness to have both men and women represented. Especially within STEM domains, women have tended to be underrepresented, and there is widespread agreement that having more representation of their perspectives is desirable (Noonan 2017). Previous research has also suggested that both team performance and CI performance increases when women are presented for reasons such as higher social sensitivity (Woolley et al. 2010; Woolley et al. 2015).

Apart from the crowd's diversity, the crowd's size (***quantity***) is also an element to consider to receive a critical mass of contributions (Raisio 2009; Zijp et al. 2016). Duckett et al. (2016) have added that *active collaboration* is required from the participants.

Ideally, the participants are both diverse and exhibit high problem-solving abilities (Hong and Page 2004). However, under certain conditions, the diversity of participants is more important than their problem-solving ability. For this to be true, a minimal level of problem-solving ability is required (Page 2007). The literature we reviewed only sparsely addresses the ***quality*** of participants, except for Edzen (2014), who suggests that participants should have relevant knowledge for the task, i.e., a *knowledge-task-fit* is given.

Along these lines, we added two self-developed factors. First, the participants need to exhibit sufficient *experience with using the platform* to contribute. Second, a participant needs to be *embedded in the network* of contributors in order for his contributions to be visible and foster discussion.

6.2 Activities

The nuances between different activity types in the literature are rather abstract. Rittel (1972) and Rittel and Webber (1973) argue that since plans or solutions to wicked problems cannot be true or false, a process in which participants share their opinions and positions is required. Many authors state the importance of discourse (Batie 2008; Ferro et al. 2013; Schoder et al. 2014), discussion (Australian Public Service Commission 2018), dialogue (Roberts 2000; Roberts 2002; Conklin 2006; Innes and Booher 2016; Brunswicker et al. 2017), negotiation (Ferro et al. 2013), deliberation (Raisio and Vartiainen 2015), reasoning of conflicting views (Pretorius 2017) and resolving of disagreements (DeLiddo and Buckingham Shum 2010). All these activities are essentially different types of communication, focusing on sharing and commenting on each other's ideas. Similarly, collaboration is viewed as a core element to addressing wicked problems (Camillus 2008; Head 2008; Xiang 2013; Head and Alford 2015; Duckett et al. 2016; Head and Xiang 2016; Tietjen and Jørgensen 2016). The literature suggests participants must share their opinions (Rittel 1972; Camillus 2008; Malone et al. 2010; Innes and Booher 2016; Pretorius 2017), knowledge (Head and Xiang 2016), as well as subjective judgment (Rittel and Webber 1973).

As these derived activities are rather abstract and difficult to measure, we further looked at activities in existing CI platforms for wicked-problem-solving. From them, we derive a set of basic activities performed by the participants. At their core, we clustered these activities into six basic types that were observed: ***Decomposition*** describes the definition and partitioning of the underlying subject (e.g., problem or task). It can be observed in the partition phase of CrowdForge (Kittur et al. 2011), the problem decomposition of PARCEL (Greene et al. 2012), or the initial breakdown of the problem into pieces in the contest webs of the Climate CoLab (Malone et al. 2017). The second type, ***creation***, is fundamental to all applications and can be described as contributions addressing the subject at hand (e.g., proposed solutions). Creation can be found in a wide range of applications (Little et al. 2010; Kittur et al. 2011; Yu and Nickerson 2011; Greene et al. 2012; Introne et al. 2013; Fuge et al. 2014; Brunswicker et al. 2017; Malone et al. 2017). The third element is the ***combination*** of a new contribution by leveraging at least two existing contributions. Examples would be the reduce phase in CrowdForge (Kittur et al. 2011), the combine phase in the contest webs of the Climate CoLab (Malone et al. 2017), or those from other applications (Little et al. 2010; Yu and Nickerson 2011; Greene et al. 2012; Fuge et al. 2014; Brunswicker et al. 2017). The fourth basic type of activity is exchanging opinions (e.g., like comments) with other participants, which is referred to as ***feedback***. In applications like Open IDEO, the possibility to comment continuously on contributions is present. Further examples of feedback functionality, for example, are described in the literature (Introne et al. 2013; Bianchi et al. 2015; Brunswicker et al. 2017; Malone et al. 2017). The fifth type of activity is ***refinement***, which is the revision of a contribution to improve its quality by editing existing content or adding new content to an existing contribution. While participants might engage in such activities within creating their content, only a few applications explicitly call for revisions, such as the Climate CoLab, OpenIDEO, or Bombardier´s YouCity Challenge (Bianchi et al. 2015; Brunswicker et al. 2017; Malone et al. 2017). The sixth and last type of activity is assessing the quality of contributions (e.g., like or vote), which can be used for subsequent decision making. This activity is referred to as ***evaluation***. Examples include the Popular Choice Award of the Climate CoLab and others (Little et al. 2010; Yu and Nickerson 2011; Introne et al. 2013; Malone et al. 2017). It is important to note that different applications currently use different configurations of these activities.

6.3 Content

Participants act on CI platforms for wicked-problem-solving by contributing content, such as ideas, comments, and votes. As such, the content dimension is strongly influenced by the participants and their collaboration. Prior research argued that it is important to gather a variety of opinions from the crowd (Camillus 2008) in order to collect diverse insights (Head and Alford 2015) (***content diversity*** - cf. diversity of participants). This diversity is important to obtain a broad, holistic view (Ireland et al. 2012), which is in line with the theory that a group's collective mind is more efficient in producing a broad spectrum of suggestions and thereby uncovers crucial facets of the problem (Jantunen et al. 2011). Furthermore, proposed solutions to wicked problems should be contextualized and integrated. Thus it is useful to combine opinions from multiple participants (Brunswicker et al. 2017). Ideally, this also includes the exchange of vastly different and even controversial perspectives (Ketter et al. 2015). Further support for the importance of content diversity stems from the argument that a solution's perceived quality to a wicked problem differs from stakeholder to stakeholder and can thus only be viewed holistically when taking all perspectives into account (Rittel and Webber 1973).

Apart from the above-mentioned inter-content and intra-content diversity, the quantity and quality of content are relevant. This relevance is supported by literature focusing on measuring knowledge contribution (e.g., in Wiertz and Ruyter 2007). While it is difficult to objectively assess the ***quality of the content***, certain baseline quality of the provided text is necessary. Looking at the extremes of ***quantity***, it might not be desirable to receive droves of unsorted and unstructured ideas and comments. The relationship could thus be described as an inverted u-shape. Nevertheless, it is also not sufficient to only have one idea – no matter how elaborate it is – as it would only represent one perspective. Thus, we included quantity as a subdimension of content.

6.4 Collective Learning

By engaging with other participants' content and interacting with each other, participants are involved in collective learning (Garavan and Carbery 2012). This impacts participants' knowledge and opinions, which is particularly important as solutions to wicked problems cannot be true or false but rather good or bad (Rittel 1972). We can differentiate three levels of collective learning, which build on each other and are a desirable sequence of progress: First, to engage in argumentative processes with other participants and derive integrative solutions, participants need to be aware of the opinions and suggestions of others. Thus, ***awareness*** of contested knowledge is desirable (DeLiddo and Buckingham Shum 2010).

Second, ***understanding*** other participants' opinions enable discussion and collaboration beyond pure awareness (Camillus 2008). This type of understanding, which is sometimes also referred to as collective understanding or shared understanding, includes participants being aware of agreements and disagreements and ways to deal with them (e.g., Conklin 2006; DeLiddo and Buckingham Shum 2010; Cajot et al. 2017; Pretorius 2017).

Third, some researchers have argued that a certain level of ***convergence*** in thoughts and solutions is desired. Eldabi (2009) argues that it is important to think about consensus when tackling wicked problems. That said, other researchers have argued that consensus might sometimes not be reachable. Nevertheless, it is still important to have all participants accept jointly created solutions and reach mutual justifiability (Raisio and Vartiainen 2015). Some authors further argue that agreement on the problem definition is a prerequisite for success (Ferro et al. 2013; Inghelbrecht et al. 2014; Pretorius 2017).

6.5 Iteration

The last success dimension addresses the interconnection between problem understanding and solution exploration and is called Iteration. One central characteristic of wicked problems is that they cannot be exhaustively formulated (Rittel 1972). One way to deal with that issue is to understand the problem better by creating potential solutions (Conklin 2001). Thus, the understanding of how to deal with the problem is changed with each potential solution put forward (Rittel and Webber 1973). The result is an ongoing iterative process of better understanding the problem and putting forward new potential solutions (Feldgen and Clua 2012). During this process, it helps if participants actively share their perspectives (Duckett et al. 2016). The necessity of iterative processes and the iterative nature of problem-solving when dealing with wicked problems is further outlined by Pacanowsky (1995), Schoder et al. (2014), Zijp et al. (2016), and others. Thus, Iteration is the fifth success dimension.

6.6 Assessment Model for the CRC

An operationalization of the assessment model for the CRC serves as a demonstration of the artifact (Eval 2 from Sonnenberg and vom Brocke 2012). The assessment model extends the derived success dimensions through data sources with which they can be assessed and potential recommended actions developed in close collaboration with the CRC.

As two of the authors of this paper were involved in running the CRC, preliminary thoughts and concepts of the assessment model were already tested during this CI platform's execution for wicked problem solving (ex-nunc). Their work included assessing the list of invited participants, continuously monitoring the number of activities on the platform by date and author (contributions, likes, votes, comments), and analyzing content distribution over participants and the constellation of combinations. The derived insights helped align facilitation activities (e.g., changes in schedule, communication with participants, assigning team constellations, adjustment of requirements) while the pilot was running and thus provided first evidence for the usefulness of the ex-nunc application of the model. During this part of the process, the demonstration was performed (Eval 2), and the design of the assessment model was refined.

Eval 2 included active engagement with platform owners and facilitators to ensure that the design is meaningful to the stakeholders, captures the problem correctly, and addresses it thoroughly. We did this by showing and demonstrating the assessment model's drafts and the derived success dimensions to the platform owner and facilitator. It became clear that there is a trade-off between completeness and parsimony, as multiple ideas to enhance the model and extend the dimensions were discussed. As discussed in the artifact development section, these conversations led to some self-developed additions to the assessment model ("s.d." in the following table). "Self-developed" shall not claim that there is no prior discussion of these factors in literature but merely provide the transparency that the addition of these factors was not inspired by literature but by practitioners.

Based on these identified dimensions and the presented literature, we derive the following assessment model (*Table 1*), which helps with operationalizing the dimensions in an actual CI online platform for wicked problems. Beyond the general assessment model, this operationalization discusses data sources and recommended actions depending on the specific data measured. These actions were derived from our expert interviews and discussions with practitioners.

(Insert Table 1)

7 Use and Case Study

We tested the applicability and usefulness of our assessment model with the CRC during and after a run. This analysis informed future runs of the CRC. In the following, we summarize insights from analyses that correspond to each success dimension (excluding Iteration). The analyses were selected in collaboration with the CRC based on the importance to the facilitation team, relevance in demonstrating the assessment model's versatility, and available data. Overall, this example application of the assessment model to the CRC demonstrates its practical applicability and usefulness. We summarize our findings in Table 1.

7.1 Assessment of Participants

Within the CRC, the goal was to recruit participants from all major regions of the world to ensure ***diversity***. For other applications, this could be different, depending on the wicked problem's scale and type. To measure the degree of achieving this goal, we compared the participants' country of origin to the regions used since the 2017 report for the UN Sustainable Development Goals (United Nations 2020). The results indicate that active participants covered six out of seven regions. Nonetheless, the vast majority of participants (55 of 81) were associated with Europe and Northern America. While this is not surprising due to the involved organizations' professional network, a greater representation from other regions would be desirable and should be considered when recruiting participants for future runs. In terms of ***quantity,*** 81 participants did suffice and met the facilitator's expectations, although there is no upper bound for that metric.

The subdimensions that we did not evaluate in this paper are stakeholder completeness and ideological diversity. While stakeholder completeness is challenging to define, it requires an in-depth analysis of the underlying wicked problem and is highly case-specific. Ideological diversity is sensitive data to gather and somewhat difficult to assess the participants' ideology. We discussed such information with the platform owners and facilitators, who considered them to be relevant. In the CRC case, the majority of participants were already very committed to sustainability and, thus, the risk of too homogeneous thinking among the participants existed. This is particularly relevant as participants oriented towards other objectives would have been beneficial in that regard. However, due to the participants' specific interest, the participants' ***quality*** in terms of knowledge-task-fit was assured.

Altogether, the success dimension participant diversity is particularly relevant, especially during the Pre-Phase of a run on a CI platform. Further, ongoing monitoring of the prevalence of diversity (in any regard) as participants join the community was considered desirable by the platform facilitators. The information should immediately feedback into the recruitment process, which is adjusted when a group is underrepresented.

7.2 Assessment of Activities

Participation in the five different micro-phases generated content in the form of contributions (both content creation and combination), likes, comments, and votes. Digital trace data on these contributions were analyzed to measure whether participation had been constant across all phases and to identify issues in the overall process. Participation was relatively constant, with one exception. A low overall number of contributions was found in Phase 5. Per our interviews, this was likely because most teams did not collaborate on the platform but rather through email and other channels. Teams submitted their contributions just before the final deadlines, leaving others little time to comment. Such an issue could be solved by informing and encouraging participants to collaborate on the platform during runtime or by enhancing the platform's collaboration features in the redesign phase.

The most important information for the platform facilitator was that a critical mass of contributions was reached. If this is not the case in certain phases, activating the participants by sending out reminders, encouraging, and rewarding participation by the process facilitators were determined to be suitable interventions. The positive impact of reminders could be shown in this evaluation. Messages were sent out on Fridays to remind people of the upcoming end of a phase. These messages did indeed result in increased participation, as the analysis of trace data showed.

High activity levels are also relevant on a diversity level, as all stakeholders must stay actively involved. We observed that six out of seven regions were covered for the first three phases, which decreased to three (Phase 4) and four (Phase 5). Concerning the ratio of female participants, we observe that the percentage primarily lies between 35 to 40%. Regarding the total number of activities, women were more active than men.

During runtime, process facilitators could reach out to sub-segments of participants and invite them to be more active. More open platforms could also use other tactics, such as targeted advertising. Facilitators could have sent out messages welcoming and encouraging such perspectives had this information been available during runtime in a structured way, as suggested in this paper.

7.3 Assessment of Content

In Phases 1 and 2, drivers of change were suggested in six different categories (social, technological, economic, environmental, political, international relations). Contributions in this phase represent ***content diversity***. The contributions in those categories ranged from 27 (societal) to 77 (environmental). As the environment is the focus of CRC, this was considered a good result.

The goal in phase 3 was to create novel and innovative combinations by using elements from different fields. Participants were asked to combine no more than four drivers from previous phases. In the 33 combinations with two or more sub-elements, 83 different drivers were used (35% of the 238 drivers). It could further be observed that a substantial number of drivers from each category was utilized in combinations. On average, 3.89 drivers of change from 2.39 different categories were used per combination. Thus, CRC generally achieved its goal of promoting diversity in the content generated by participants.

Nonetheless, one area for potential improvement is to increase further the drivers of change used in combinations. Activities on online platforms often follow a power-law distribution. One idea on leveraging a broader spectrum of drivers of change was to recommend random or algorithmically selected sub-elements for combination as inspiration for the participants. Social recommender systems research might be a starting point (Arazy et al. 2010).

During the exercise's runtime, the use of NLP to measure the **similarity** between the underlying contributions and analyzing the distance between combined elements were considered. Methods such as word2vec may help in that regard (Mikolov et al. 2013). Such tools have recently been suggested in the realm of wicked problems by Gimpel et al. (2020).

Platform owners and process facilitators stated that they would use such analyses in the future to track incoming suggestions and analyze if some areas of expertise are underrepresented. For instance, a technological perspective was underrepresented in a later run for lack of experts from the field. Thus, the platform owner sent messages to the participants welcoming such contributions. So far, this has been done intuitively or based on periodic reports. However, as suggested by our assessment model, a more systematic and continuous reporting would be appreciated to pursue guiding interventions more aggressively.

7.4 Assessment of Collective Learning

Crucial to addressing wicked problems is that participants know about each other's opinions and become aware of their mutual agreements and disagreements. Thus, creating ***awareness*** among the participants is a relevant success factor for collective learning. Initially, it was assessed to which extent awareness among the participants is observable. The facilitator could actively steer awareness by either summarizing the ongoing discussion on the platform for the participants (Gimpel et al. 2020) or even nudging single participants to take a closer look into specific contributions.

One possibility is to track awareness by assessing which participants have read specific contributions to assess how well-informed each participant is. In the CRC, 50 participants did interact with contributions from others. On average, they interacted with 12.1 contributions (median: 7.5, min: 1, max: 71) throughout the process. At any point in the process, this information can be used to spark further involvement of the participants and highlight "unread" contributions to each participant.

Following awareness, collective ***understanding*** is crucial for collective learning. Therefore, participants need to become aware of whether other participants agree or disagree with specific contributions. The CRC was designed primarily to register positive reactions via likes, votes, or comments – negative reactions could only be expressed via comments. Thus, such positive reactions have been predominant (423 likes, 285 votes, 57 comments). To foster collective understanding, changing the way participants can react to contributions became a possible adjustment within the CRC. In the redesign phase, likes and up-votes could be replaced by up-votes and down-votes, the introduction of star ratings, or other mechanisms.

For collective learning, mutual understanding is necessary. From the outside, this is hardly assessable. Nevertheless, interactions between participants could be used as a proxy for mutual understanding. A balanced number of interactions going in and out of a participant could indicate to facilitators that participants express their opinion and listen to others. Achieving such a balance is desirable to some extent. Thus, based on such information, facilitators can give recommendations to participants on how to adjust their behavior in order to facilitate collective learning. Most participants had non-zero in- and out-degrees in the CRC, meaning that most participants shared their opinions and received recognition for their contributions. Additionally, the in-degree score is not only centered around a few participants but widely spread across all the participants (mean in-degree: 6.31, median in-degree: 4, standard deviation in-degree: 7.83, maximum in-degree: 31, mean out-degree: 6.67, median out-degree: 3, standard deviation out-degree: 7.19, maximum out-degree: 38). Thus, it seems as if the crowd as a whole (widespread out-degree) is attending to and responding to contributions made by a wide range of peers (widespread in-degree). This pattern is congruent with the goal of the CRC to have broad engagement by participants.

In a similar vein, the assessment of relationships to a diverse group of other participants is important to ensure that connections are not only made with like-minded others. In this vein, cross-fertilization should be measured and encouraged (Gimpel et al. 2020).

7.5 Summary of the Findings

We summarize the key findings from the previous subsections in Table 2. For selected (sub-)dimensions, we outline success factors that appeared to be suitable to be measured and the respective findings we could draw from them.

Table 2. Summary of Model Application to the CRC

Dimension	Subdimension	Success factor	Core findings
Participants	Diversity	Regional diversity	Need for attracting a global crowd in pre-phase to ensure sufficient contribution in runtime-phase
		Stakeholder completeness	Highly case-specific data, significant effort required to define that dimension
		Ideological completeness	Sensitive data that is difficult to gather, facilitators and owners of the platform need to decide whether the information is relevant
Activities	-	Activity levels across all micro-phases	Critical mass of contributions needs to be reached, involvement of all participants through reminders, incentivizing on-platform collaboration in all phases
		Gender diversity	Sufficient share of activity by women, diversity implies activity by the sub-groups
		Regional diversity	Contributions from a majority of regions recorded, some regions challenging to involve, diversity implies activity by the sub-groups
Content	Diversity	Content reuse, content diversity	Successful combination of content, sparking inspiration among participants by automated suggestions for content combination
		Content similarity	Literature already outlines the benefits of similarity assessment
Collective Learning	Understanding	Reactions from participants	Design the platform to encourage differentiated (non-positive) feedback
		Distribution of in- and out-degree	Assuring that interaction among the participants is balanced
	Awareness	Views by participants	Nudging participants to pay attention to unread or potentially relevant contributions

8 Discussion

8.1 Theoretical Implications

While many contributions regarding wicked-problem-solving and the operation of CI platforms exist, no paper has integrated these views into an assessment model with dedicated recommendations and actions for platform management. We provide a framework for owners and facilitators of CI applications, supporting them in setting up and executing their endeavors successfully with our work. The underlying model and subsequent systematic structuring of the findings in the form of success dimensions contribute to the literature by providing a comprehensive overview of crucial factors when dealing with wicked problems collectively. As suggested by Gregor and Jones [84], we provide a design theory to assess the quality of structures and processes in CI endeavors. Gregor and Jones (2007) propose that a design theory consists of eight components. In *Table 3*, we refer to these components as they relate to the design knowledge originating from this study.

Besides, our paper provides insight into facilitation actions for managing platform success. In our evaluation, we give first indications that such efforts may be highly fruitful. This initial list of actions creates a basis for future behavioral research in the area that may detail the effects of such facilitation actions on the individuals participating in the CI exercises and the different solution qualities that result from well-managed platforms. The assessment model serves as the theoretical foundation for future work investigating the facilitation of CI exercises. While this work's focus was on CI applications, the identified success dimensions may prove valuable for other kinds of crowdsolving exercises as processes on these platforms work comparably. Therefore, we also contribute to a broader range of applications utilizing CI with this work.

Table 3. Eight Components of an IS Design Theory (Gregor & Jones, 2007) and Specific Manifestation in this Study

	Description
Purpose and scope	Support owners and facilitators of CI platforms for solving wicked problems in assessing the quality of their structures and processes and derive actions for managing the platform's success.
Constructs	Relating to purpose and scope: Wicked problems, Collective intelligence Relating to the dimensions of the assessment model: Participants, Activities, Content, Collective Learning, Iteration, Action Relating to the subdimensions of the assessment model: Diversity, Quantity, Quality, Decomposition, Creation, Combination, Feedback, Refinement, Evaluation, Awareness, Understanding, Convergence
Principle of form and function	An assessment model is provided, which helps platform owners and facilitators measure the five success dimensions for wicked-problem-solving. The artifact can be used before, during, and after the runtime phase and for potential platform and process (re)design.
Artifact mutability	Depending on how a platform assembles the activities, the application of the assessment model is different. It is thus customizable.
Testable propositions	Assessing the dimensions and applying the recommended choice of action will improve platform success and, hence, improve the quality of the developed solutions. Given the inherent difficulty of measuring quality, surrogate endpoints for testing the assessment model's practical value are practitioners' adoption of the model and their satisfaction with using it.
Justificatory knowledge	The success dimensions derive from the literature on wicked problems, and the activities are inferred and synthesized from a review of existing CI platforms for solving wicked problems.
Principle of implementation	The assessment model is enhanced through suggested measures, and action choices are proposed based on the results.
Expository instantiation	A real-world example for selected dimensions is performed based on data from the collective intelligence platform CRC.

8.2 Practical Implications

From a practical perspective, platform owners and facilitators can learn about success factors, which they should consider in their processes and setup of their endeavors. We recommend facilitation actions facilitators can directly apply and profit from our model and mutate it to fit their individual needs of the platform. In addition, they can profit from the evaluation and learnings from our instantiation at the CRC. An instantiation of the assessment model could serve as a valuable tool for decision support by optimizing processes based on metrics and, thus, inherently improving solution quality. Practitioners aiming to utilize a collective to tackle a wicked problem may find this paper helpful for designing a platform to do so. Lastly, others may profit from our findings as it opens avenues for additional revenue models, such as consulting to establish a custom assessment model tailored for the facilitators' needs.

9 Future Work and Conclusion

The research is subject to limitations. Our analysis of existing literature focused on wicked problems and did not further consider the broader literature on online collaboration beyond wicked problems. Another limitation can be seen in the model's lack of specific and quantitatively measurable metrics tied to the subdimensions. One future step in research could be defining a corresponding set of metrics, which is specific enough to be directly implemented and broad enough to provide a reasonable selection of potential metrics for a wide range of applications in different realms. While more research into this direction would certainly help practitioners, we believe that it is crucial to deal with wicked problems to consider the individual nature of the problem and the corresponding application. A third limitation is the evaluation of the model, which is grounded in its application to one specific CI application, namely the CRC. The model would thus benefit from future research applying it to multiple CI systems in different environments. Furthermore, a longitudinal study design could investigate which actions prove to be more successful than others.

This paper presents an assessment model for analyzing CI applications for wicked problems as an idea's quality cannot be observed ex-ante. Thus, both owners and facilitators of CI applications need decision support to ensure their endeavors' success. We stick to the idea of Donabedian (1966) that the success of a treatment – here facilitation and management of CI endeavors – can be ensured by ensuring that both the structure and the process of the treatment meet quality criteria.

The resulting assessment model is grounded in an extensive literature review and enhanced via an iterative process of expert interviews and insights from existing CI endeavors. The assessment model consists of five success dimensions and a total of nine subdimensions. The success dimensions cover success factors for all relevant phases of a CI endeavor, and dedicated facilitation actions can be drawn based on the insights gained from the application of our assessment model. Besides, the assessment model helps with the redesign of CI platforms with its insights. We draw connections between CI exercises' processes to solve wicked problems and the success factors to give insight into which processes could be enhanced or monitored by the assessment model. Based on real-world data and close collaboration with an existing CI platform, we evaluate the assessment model and provide guidance on how the model can be used. We suggest different types of analysis as inspiration for defining suitable metrics and highlighted the importance of considering both qualitative and quantitative assessment approaches. Altogether the results indicate that the assessment model is a helpful tool for platform owners and facilitators.

Acknowledgements

We are grateful for funding and support from the German Research Foundation (project 343128888).

References

Alrøe, Hugo F.; Noe, Egon (2014): Second-order science of interdisciplinary research: A polyocular framework for wicked problems.

Arazy, Ofer; Kumar, Nanda; Shapira, Bracha (2010): A Theory-Driven Design Framework for Social Recommender Systems. In *Journal of the Association for Information Systems* 11 (9), pp. 455–490.

Australian Public Service Commission (2018): Tackling wicked problems : A public policy perspective. Available online at https://www.apsc.gov.au/tackling-wicked-problems-public-policy-perspective, updated on 6/12/2018, checked on 10/26/2020.

Batie, Sandra S. (2008): Wicked Problems and Applied Economics. In *American Journal of Agricultural Economics* 90 (5), pp. 1176–1191.

Bianchi, Joost; Knopper, Yuri; Eris, Ozgur; Badke-Schaub, Petra; Roussos, Lampros (2015): Online Ways of Sharedness : A Syntactic Analysis of Design Collaboration in OpenIDEO. In Christian Weber, Stephan Husung, Marco Cantamessa, Gaetano Cascini, Dorian Marjanovic, Francesca Montagna (Eds.): Design organisation and management. Glasgow: Design Society (DS / Design Society, 80,3), pp. 339–348.

Bonabeau, Eric (2009): Decisions 2.0: The power of collective intelligence. In *MIT Sloan Management Review* 50 (2), pp. 45–52.

Brunswicker, Sabine; Bilgram, Volker; Fueller, Johann (2017): Taming wicked civic challenges with an innovative crowd. In *Business Horizons* 60 (2), pp. 167–177.

Cajot, S.; Peter, M.; Bahu, J.-M.; Guignet, F.; Koch, A.; Maréchal, F. (2017): Obstacles in energy planning at the urban scale. In *Sustainable Cities and Society* 30, pp. 223–236.

Camillus, John C. (2008): Strategy as a wicked problem. In *Harvard Business Review* 86 (5), p. 98.

Churchmann, C. West (1967): Guest Editorial: Wicked Problems. In *Management Science* 14 (4), pp. 141–142. Available online at www.jstor.org/stable/2628678.

Conklin, Jeff (2001): Wicked problems and fragmentation. In *Unpublished working paper*.

Conklin, Jeff (2006): Wicked problems & social complexity: CogNexus Institute San Francisco, CA.

Davies, Kathryn K.; Fisher, Karen T.; Dickson, Mark E.; Thrush, Simon F.; Le Heron, Richard (2015): Improving ecosystem service frameworks to address wicked problems. In *Ecology and Society* 20 (2). Available online at http://www.jstor.org/stable/26270210.

DeLiddo, Anna; Buckingham Shum, Simon (2010): Cohere: A prototype for contested collective intelligence.

Donabedian, Avedis (1966): Evaluating the Quality of Medical Care. In *The Milbank Memorial Fund Quarterly* 44 (3), p. 166.

Duckett, D.; Feliciano, D.; Martin-Ortega, J.; Munoz-Rojas, J. (2016): Tackling wicked environmental problems: The discourse and its influence on praxis in Scotland. In *Landscape and Urban Planning* 154, pp. 44–56.

Durward, David; Blohm, Ivo; Leimeister, Jan Marco (2016): Crowd Work. In *Business & Information Systems Engineering* 58 (4), pp. 281–286.

Edzen, Svante (2014): Table-Top Exercises for Emergency Management: Tame Solutions for Wicked Problems. In Ralph H. Sprague (Ed.): 47th Hawaii International Conference on System Sciences (HICSS), 2014. 6 - 9 Jan. 2014, Waikoloa, Hawaii ; proceedings. 2014 47th Hawaii International Conference on System Sciences (HICSS). Waikoloa, HI, 1/6/2014 - 1/9/2014. Shidler College of Business; IEEE Computer Society; Annual Hawaii International Conference on System Sciences; Hawaii International Conference on System Science; HICSS. Piscataway, NJ: IEEE, pp. 1978–1985.

Eldabi, Tillal (2009): Implementation issues of modeling healthcare problems: Misconceptions and lessons. In Manuel D. Rossetti (Ed.): Proceedings of the 2009 Winter Simulation Conference. December 13 - 16, 2009, Austin, Texas, U.S.A. ; inclusion of MASM (Modeling and analysis of semiconductor manufacturing). 2009 Winter Simulation Conference - (WSC 2009). Austin, TX, USA, 12/13/2009 - 12/16/2009. Institute of Electrical and Electronics Engineers; Winter Simulation Conference; WSC; MASM (Modeling and analysis of semiconductor manufacturing). Piscataway, NJ: IEEE, pp. 1831–1839.

Elia, Gianluca; Margherita, Alessandro (2018): Can we solve wicked problems? A conceptual framework and a collective intelligence system to support problem analysis and solution design for complex social issues. In *Technological Forecasting and Social Change* 133, pp. 279–286.

Feldgen, Maria; Clua, Osvaldo (2012): Promoting design skills in distributed systems. In : 2012 Frontiers in Education Conference proceedings (FIE 2012). Seattle, Washington, USA, 3 - 6 October 2012. 2012 IEEE Frontiers in Education Conference (FIE). Seattle, WA, USA, 10/3/2012 - 10/6/2012. American Society for Engineering Education; IEEE Computer Society; IEEE Education Society; Annual Frontiers in Education Conference; FIE. Piscataway, NJ: IEEE, pp. 1–6.

Ferro, Enrico; Loukis, Euripidis N.; Charalabidis, Yannis; Osella, Michele (2013): Policy making 2.0: From theory to practice. In *Government Information Quarterly* 30 (4), pp. 359–368.

Fleming, A.; Howden, S. M. (2016): Ambiguity: A new way of thinking about responses to climate change. In *The Science of the Total Environment* 571, pp. 1271–1274.

Fuge, Mark; Tee, Kevin; Agogino, Alice; Maton, Nathan (2014): Analysis of Collaborative Design Networks: A Case Study of OpenIDEO. In *Journal of Computing and Information Science in Engineering* 14 (2), Article 021009.

Garavan, Thomas N.; Carbery, Ronan (2012): Collective Learning. In Norbert M. Seel (Ed.): Encyclopedia of the sciences of learning. With 68 tables. New York, NY: Springer (Springer reference), pp. 646–649.

Gimpel, Henner (2015): Interview with Thomas W. Malone on “collective intelligence, climate change, and the future of work”. In *Business & Information Systems Engineering* 57 (4), pp. 275–278.

Gimpel, Henner; Graf-Drasch, Valerie; Laubacher, Robert J.; Wöhl, Moritz (2020): Facilitating like Darwin: Supporting cross-fertilisation in crowdsourcing. In *Decision Support Systems* 132, p. 113282.

Greene, Kshanti; Thomsen, Dan; Michelucci, Pietro (2012): Massively collaborative problem solving: new security solutions and new security risks. In *Secur Inform* 1 (1).

Gregor, Shirley (2006): The Nature of Theory in Information Systems. In *MIS Quarterly* 30 (3), pp. 611–642.

Gregor, Shirley; Hevner, Alan R. (2013): Positioning and Presenting Design Science Research for Maximum Impact. In *MIS Quarterly* 37 (2), pp. 337–355.

Gregor, Shirley; Jones, David (2007): The anatomy of a design theory. In *Journal of the Association for Information Systems* 8 (5).

Head, Brian W. (2008): Wicked problems in public policy. In *Public Policy* 3 (2), p. 101.

Head, Brian W.; Alford, John (2015): Wicked Problems. In *Administration & Society* 47 (6), pp. 711–739.

Head, Brian W.; Ross, Helen; Bellamy, Jennifer (2016): Managing wicked natural resource problems: The collaborative challenge at regional scales in Australia. In *Landscape and Urban Planning* 154, pp. 81–92.

Head, Brian W.; Xiang, Wei-Ning (2016): Working with wicked problems in socio-ecological systems: More awareness, greater acceptance, and better adaptation. In *Landscape and Urban Planning* 154, pp. 1–3.

Hevner, Alan; vom Brocke, Jan; Maedche, Alexander (2019): Roles of Digital Innovation in Design Science Research. In *Business & Information Systems Engineering* 61 (1), pp. 3–8.

Hevner, Alan R.; March; Park; Ram (2004): Design Science in Information Systems Research. In *MIS Quarterly* 28 (1), p. 75.

Hong, Lu; Page, Scott E. (2004): Groups of diverse problem solvers can outperform groups of high-ability problem solvers. In *Proceedings of the National Academy of Sciences of the United States of America* 101 (46), pp. 16385–16389.

Inghelbrecht, Linde; Dessein, Joost; van Huylenbroeck, Guido (2014): The non-GM crop regime in the EU: How do Industries deal with this wicked problem? In *NJAS - Wageningen Journal of Life Sciences* 70-71, pp. 103–112.

Innes, Judith E.; Booher, David E. (2016): Collaborative rationality as a strategy for working with wicked problems. In *Landscape and Urban Planning* 154, pp. 8–10.

Introne, Joshua; Laubacher, Robert; Olson, Gary; Malone, Thomas (2013): Solving wicked social problems with socio-computational systems. In *KI-Künstliche Intelligenz* 27 (1), pp. 45–52.

Ireland, Vernon; Rapaport, Barbara; Omarova, Amina (2012): Addressing Wicked Problems in a Range of Project Types. In *Procedia Computer Science* 12, pp. 49–55.

Jantunen, Sami; Lehtola, Laura; Gause, Donald C.; Dumdum, U. Rex; Barnes, Raymond J. (2011): The challenge of release planning. In Marjo Kauppinen (Ed.): 2011 Fifth International Workshop on Software Product Management (IWSPM 2011). Trento, Italy, 30 August 2011 ; [part of the 19th IEEE International Requirements Engineering Conference. 2011 5th International Workshop on Software Product Management (IWSPM). Trento, Italy, 8/30/2011 - 8/30/2011. Institute of Electrical and Electronics Engineers; International Workshop on Software Product Management; IWSPM; IEEE International Requirements Engineering Conference (RE). Piscataway, NJ: IEEE, pp. 36–45.

Johnson, Christopher M. (2001): A survey of current research on online communities of practice. In *The Internet and Higher Education* 4 (1), pp. 45–60.

Ketter, Wolfgang; Peters, Markus; Collins, John; Gupta, Alok (2015): Competitive Benchmarking: An IS Research Approach to Address Wicked Problems with Big Data and Analytics. In *MIS Quarterly*.

Kittur, Aniket; Smus, Boris; Khamkar, Susheel; Kraut, Robert E. (2011): CrowdForge. In Jeff Pierce (Ed.): Proceedings of the 24th annual ACM symposium on User interface software and technology. the 24th annual ACM symposium. Santa Barbara, California, USA, 10/16/2011 - 10/19/2011. ACM Special Interest Group on Computer Graphics and Interactive Techniques; ACM Special Interest Group on Computer-Human Interaction. New York, NY: ACM, p. 43.

Kornish, Laura J.; Ulrich, Karl T. (2014): The Importance of the Raw Idea in Innovation: Testing the Sow's Ear Hypothesis. In *Journal of Marketing Research* 51 (1), pp. 14–26.

Levin, Kelly; Cashore, Benjamin; Bernstein, Steven; Auld, Graeme (2012): Overcoming the tragedy of super wicked problems: constraining our future selves to ameliorate global climate change. In *Policy Sciences* 45 (2), pp. 123–152.

Little, Greg; Chilton, Lydia B.; Goldman, Max; Miller, Robert C. (2010): Exploring iterative and parallel human computation processes. In Unknown (Ed.): Proceedings of the ACM SIGKDD Workshop on Human Computation. the ACM SIGKDD Workshop. Washington DC, 7/25/2010 - 7/25/2010. ACM Special Interest Group on Knowledge Discovery in Data; ACM Special Interest Group on Management of Data. New York, NY: ACM, p. 68.

Malone, Thomas W. (Ed.) (2015): Handbook of Collective Intelligence: The MIT Press. Available online at http://search.ebscohost.com/login.aspx?direct=true&scope=site&db=nlebk&AN=1092306.

Malone, Thomas W.; Laubacher, Robert; Dellarocas, Chrysanthos N. (2010): The collective intelligence genome. In *MIT Sloan Management Review* 51 (3), pp. 21–32.

Malone, Thomas W.; Laubacher, Robert; Introne, Josh; Klein, Mark; Abelson, Hal; Sterman, John; Olson, Gary (2009): The climate collaboratorium: Project overview. In *MIT Center for Collective Intelligence Working Paper* 3 (2009-03).

Malone, Thomas W.; Nickerson, Jeffrey V.; Laubacher, Robert J.; Fisher, Laur Hesse; Boer, Patrick de; Han, Yue; Towne, W. Ben (2017): Putting the Pieces Back Together Again. In Charlotte P. Lee, Steve Poltrock, Louise Barkhuus, Marcos Borges, Wendy Kellogg (Eds.): CSCW '17. Proceedings of the 2017 ACM Conference on Computer Supported Cooperative Work and Social Computing : Feb. 25-Mar. 1, 2017, Portland, OR, USA. With assistance of Charlotte P. Lee, Steve Poltrock. CSCW '17: Computer Supported Cooperative Work and Social Computing. Portland Oregon USA, 25.02.17 - 01.03.17. CSCW; Association for Computing Machinery; ACM Conference on Computer Supported Cooperative Work and Social Computing. New York, NY: ACM Association for Computing Machinery (malone bernstein collective intelligence handbook), pp. 1661–1674.

March, Salvatore T.; Smith, Gerald F. (1995): Design and natural science research on information technology. In *Decision Support Systems* 15 (4), pp. 251–266.

Michelucci, Pietro; Dickinson, Janis L. (2016): The power of crowds. In *Science (New York, N.Y.)* 351 (6268), pp. 32–33.

Mikolov, Tomas; Chen, Kai; Corrado, Greg; Dean, Jeffrey (2013): Efficient Estimation of Word Representations in Vector Space. Available online at https://arxiv.org/pdf/1301.3781.

Noonan, Ryan (2017): Women in STEM: 2017 Update. ESA Issue Brief# 06-17. In *US Department of Commerce*.

Pacanowsky, Michael (1995): Team tools for wicked problems. In *Organizational Dynamics* 23 (3), pp. 36–51.

Page, Scott E. (2007): Making the Difference: Applying a Logic of Diversity. In *Academy of Management Perspectives* 21 (4), pp. 6–20.

Peffers, Ken; Tuunanen, Tuure; Rothenberger, Marcus A.; Chatterjee, Samir (2007): A Design Science Research Methodology for Information Systems Research. In *Journal of Management Information Systems* 24 (3), pp. 45–77.

Potter, Andrew; McClure, Melody; Sellers, Ken (2010): Mass collaboration problem solving: A new approach to wicked problems. In : 2010 International Symposium on Collaborative Technologies and Systems. CTS 2010 ; Chicago, Illinois, USA, 17 - 21 May 2010. 2010 International Symposium on Collaborative Technologies and Systems. Chicago, IL, USA, 5/17/2010 - 5/21/2010. Institute of Electrical and Electronics Engineers; International Symposium on Collaborative Technologies and Systems; CTS. Piscataway, NJ: IEEE, pp. 398–407.

Pretorius, Carianne (2017): Exploring Procedural Decision Support Systems for Wicked Problem Resolution. In *South African Computer Journal* 29 (1).

Pries-Heje; Baskerville (2008): The Design Theory Nexus. In *MIS Quarterly* 32 (4), p. 731.

Raisio, Harri (2009): Health care reform planners and wicked problems: Is the wickedness of the problems taken seriously or is it even noticed at all? In *Journal of Health Organization and Management* 23 (5), pp. 477–493.

Raisio, Harri; Vartiainen, Pirkko (2015): Accelerating the public's learning curve on wicked policy issues: results from deliberative forums on euthanasia. In *Policy Sciences* 48 (3), pp. 339–361.

Rittel, Horst (1972): On the planning crisis: Systems analysis of the 'first and second generations'. In *Bedriftskonomen* 8, pp. 390–396.

Rittel, Horst W. J.; Webber, Melvin M. (1973): Dilemmas in a general theory of planning. In *Policy Sciences* 4 (2), pp. 155–169.

Roberts, Nancy (2000): Wicked problems and network approaches to resolution. In *International Public Management Review* 1 (1), pp. 1–19.

Roberts, Nancy C. (2002): 1. Calls for dialogue. In *The Transformative Power of Dialogue*, pp. 3–24.

Schoder, Detlef; Putzke, Johannes; Metaxas, Panagiotis Takis; Gloor, Peter A.; Fischbach, Kai (2014): Information systems for "wicked problems". In *Business & Information Systems Engineering* 6 (1), pp. 3–10.

Sharts-Hopko, Nancy C. (2013): Tackling complex problems, building evidence for practice, and educating doctoral nursing students to manage the tension. In *Nursing Outlook* 61 (2), pp. 102–108.

Skoll Global Threats Fund (Ed.) (2017): Imagining the Unpredictable. An Experiment in Crowdsourcing the Risks of a Complex and Uncertain World. With assistance of Christina Cook, Robert Laubacher, Amy Luers, Bessma Mourad, Dominik Parak, Jonathan Star, Alex Wolk. Available online at https://climateriskscolab.org/PSC2017.pdf, checked on 1/13/2021.

Sonnenberg, Christian; vom Brocke, Jan (2012): Evaluations in the Science of the Artificial – Reconsidering the Build-Evaluate Pattern in Design Science Research. In Ken Peffers, Marcus A. Rothenberger, Bill Kuechler (Eds.): Design science research in information systems. Advances in theory and practice; 7th international conference, vol. 7286. Las Vegas, NV, USA, 14/05/2012 - 15/05/2012. DESRIST. Berlin: Springer (SpringerLink Bücher, 7286), pp. 381–397.

Strauss, Anselm; Corbin, Juliet (1990): Open coding. In *Basics of Qualitative Research: Grounded Theory Procedures and Techniques* 2 (1990), pp. 101–121.

Tatham, Peter; Houghton, Luke (2011): The wicked problem of humanitarian logistics and disaster relief aid. In *Journal of Humanitarian Logistics and Supply Chain Management* 1 (1), pp. 15–31.

Tietjen, Anne; Jørgensen, Gertrud (2016): Translating a wicked problem: A strategic planning approach to rural shrinkage in Denmark. In *Landscape and Urban Planning* 154, pp. 29–43.

United Nations (2020): SDG Indicators. Regional groupings used in Report and Statistical Annex. Available online at https://unstats.un.org/sdgs/indicators/regional-groups/, updated on 11/18/2020, checked on 11/18/2020.

Wiertz, Caroline; Ruyter, Ko de (2007): Beyond the Call of Duty: Why Customers Contribute to Firm-hosted Commercial Online Communities. In *Organization Studies* 28 (3), pp. 347–376.

Woolley, Anita Williams; Aggarwal, Ishani; Malone, Thomas W. (2015): Collective Intelligence and Group Performance. In *Current Directions in Psychological Science* 24 (6), pp. 420–424.

Woolley, Anita Williams; Chabris, Christopher F.; Pentland, Alex; Hashmi, Nada; Malone, Thomas W. (2010): Evidence for a collective intelligence factor in the performance of human groups. In *Science (New York, N.Y.)* 330 (6004), pp. 686–688.

Xiang, Wei-Ning (2013): Working with wicked problems in socio-ecological systems: Awareness, acceptance, and adaptation. In *Landscape and Urban Planning* 110 (110), pp. 1–4.

Ye, Hua; Kankanhalli, Atreyi (2013): Leveraging Crowdsourcing for Organizational Value Co-Creation. In *CAIS* 33.

Yu, Lixiu; Nickerson, Jeffrey V. (2011): Cooks or cobblers? In Desney Tan, Geraldine Fitzpatrick, Carl Gutwin, Bo Begole, Wendy A. Kellogg (Eds.): Conference proceedings and extended abstracts / the 29th Annual CHI Conference on Human Factors in Computing Systems. CHI 2011, Vancouver, BC, May 7 - 12, 2011. the 2011 annual conference. Vancouver, BC, Canada, 5/7/2011 - 5/12/2011. Association for Computing Machinery; Annual CHI Conference on Human Factors in Computing Systems; CHI. New York, NY: ACM, p. 1393.

Zijp, Michiel C.; Posthuma, Leo; Wintersen, Arjen; Devilee, Jeroen; Swartjes, Frank A. (2016): Definition and use of Solution-focused Sustainability Assessment: A novel approach to generate, explore and decide on sustainable solutions for wicked problems. In *Environment International* 91, pp. 319–331.

Appendix: Process Phases in a Design-Evaluate-Construct-Evaluate pattern (Sonnenberg and vom Brocke 2012) and Specific Manifestation in this Study

Process phase	**Methods**	**Output**	**Criteria (for evaluation phases)**	**Paper section**
Problem identification	Expert interview	Draft problem statement and design objective		
Justification (Eval1)	Literature review, expert interviews,	Problem statement, research gap, design purpose and scope	Importance, novelty	1, 2 and 5
Design	Literature review, logical reasoning, conceptual modeling	Draft of the assessment framework		
Demonstration (Eval2)	Interviews, logical reasoning, demonstration	Validated design specifications, justified design methodology	Correctness, completeness, level of detail, meaningfulness to stakeholders	6
Construct	Prototyping, expert interviews	Instantiation of the assessment model		
Prototype (Eval3)	Demonstration, expert interviews	Validated instantiation of artifact	Consistency with specifications, feasibility, applicability	6
Use	Application to CRC	Application and assessment of the model		
Case Study (Eval4)	Case study, expert interview	Validated artifact in a naturalistic setting	Applicability and usefulness in practice, impact on environment and users	7

About the Authors

Henner Gimpel is the Chair of Digital Management at the University of Hohenheim, is a member of the Research Center for Information Management (FIM), and is the academic director of the Digital Leadership Academy. His research focuses on the analysis and design of digitalization, specifically on socio-technical information systems where people, information, and digital technologies interact. His goals are to develop and use information systems that are both human-friendly and economically effective, while also analyzing individual acceptance and use of digital technologies. He often focuses on individuals in various roles, such as consumers, customers, patients, employees, and/or users who interact with information systems.

Robert Laubacher examines how technological advances over the past century—most recently innovations in communications and computing—have transformed work, organizational practices, and social patterns. His work on MIT Center for Collective Intelligence's (CCI) CoLab platforms seeks to harness the collective intelligence of large numbers of people, from all around the world, to address big, complex problems. He came to MIT in the late 1990s to join the Initiative on Inventing the Organizations of the 21st Century (21C), which examined how information technology was transforming business organizations and how those changes were reshaping employment arrangements. He subsequently worked on project that examined the mechanisms by which information technology generates organizational benefits and how the structure of social networks affects the performance of work groups.

Dominik Parak. After graduating in Business and Information Systems Engineering at the University of Augsburg, Dominik Parak joined the Elite Graduate Program "Finance & Information Management" at the Technical University of Munich, the University of Augsburg, and the University of Bayreuth with a focus on Business and Information Systems Engineering. As part of his master thesis, he spent one semester at Massachusetts Institute of Technology (Boston, USA) as visiting student. He gained practical experiences at Salesforce and Strategy& before joining the Boston Consulting Group as Consultant.

Manfred Schoch. After a 2.5-year vocational training program at Daimler AG, he continued his education with an undergraduate degree in Business Information Systems at the University of Augsburg, Germany, which he completed in 2014. During his subsequent graduate studies, he spent one semester in the MBA program of the Joseph M. Katz School of Business at the University of Pittsburgh, Pennsylvania, USA. He then received his graduate degree in Information-oriented Business Administration in 2017 from the University of Augsburg. During his studies, Manfred Schoch was able to gain substantial practical experience within Germany and abroad. The companies he worked for include Mercedes-Benz Direct (London, UK), Allianz BV (Munich, Germany), and the Bank of New York Mellon (Pittsburgh, PA, USA). Parallel to his studies he also worked at interactivelabs as a Social Media Analyst, and at the Research Center FIM as a research assistant, both in Augsburg, Germany. From April 2017 until December 2021, he has been a Doctoral Candidate and Teaching Assistant at the FIM Research Center. Since January 2022 he is a post-doc at FIM.

Moritz Wöhl has a background in Business and Information Systems Engineering. During his bachelor's studies at the University of Augsburg, Germany, he spent a semester at the Universitet Örebro in Sweden. Afterwards, he joined the Elite Graduate Program "Finance & Information Management" at the Technical University of Munich, the University of Augsburg, and the University of Bayreuth with a focus on Business and Information Systems Engineering. As part of his master thesis, he spent a semester at the Center for Collective Intelligence at the Massachusetts Institute of Technology (Boston, USA) as visiting student. He gained practical experiences at AraCom IT Services, Senacor Technologies, Hilti, and Munich Airport. He started as a student assistant at FIM Research Center for Information Management in March 2013 and has been working as a researcher in Augsburg since November 2019.