Massive Open Online Research: An Approach to Deal with Wicked Problems

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Abstract--**Humans are hardwired as problem-solvers. Professional education, in particular, enables us to solve complex problems. Even decades ago, we could safely send a crew to the moon and back. A moon-bound project is a very challenging and complex problem, but it is a tame one. The problem is clearly defined and the challenge becomes how to find the best solution. As the world and issues become more interconnected, there is a different type of problem in the horizon - "wicked" problems. A wicked problem is normally complex and challenging, but differs from the "tame" problem because there is no agreement in terms of problem definition. A wicked problem does not allow for the "choice" of best solution. Solutions tend to only mitigate the problem and sometimes generate unpredictable consequences. For instance, climate change is an issue that requires a level of ingenuity that cannot be achieved by a limited group of people, regardless how brilliant they are. It cannot be addressed by our dominant scientific, reductionist, discipline-based, and proprietary approach either. This paper proposes Massive Online Open Research (MOOR) as a better approach to deal with wicked problems. In terms of organization, this paper includes a literature review on online collaboration, focusing on the dynamics of knowledge creation and innovation. Selected open online research initiatives are used to contextualize the literature review. Based on the literature review and real cases, a MOOR framework is presented and discussed. Limitations and opportunities for future research are also included.**

I. INTRODUCTION

Humans are hardwired as problem-solvers. Professional education offers an approach that enables us to solve the most complex problems, provided we have the correct amount of time, resources, and effort. Professional and technical prowess enabled us to achieve incredible outcomes [1]. If we compare the world of today with the world of 100 years ago, we will easily see how far we have gone. Nevertheless, according to sources [2] and [3] the future is bleak. Environmentally-speaking, our monolithic solutions cannot secure access to food, shelter, and energy in the future without unexpected consequences. Moreover, according to source [4] the traditional, disciplinary-based, scientific approach has done a very poor job addressing social and environmental problems. They particularly fail to perceive interconnections amid the multiple variables. The professional, Newtonian, cognitive style is not in line with the contemporary notion of interacting, open systems. Essentially, such approach mimics the cognitive style of scientists and employs the approach of engineering to problem-solving [1]. Environmental and social problems are not just complex problems; according to Brown et al [2] they are very hard to properly define. They involve incomplete or contradictory knowledge, a large number of diverging opinions, they impose a broad economic burden and they naturally display interconnectivity with other problems [5]. Buchanan [6] concluded these types of problems don't fit within any specific subject matter. They are what Rittel and Webber [1] would call a *wicked* problem. To approach them new pathways should be explored rather than following existing ones [2] [7]. Referring to the management of technology field as whole, James Utterback [8] called for ambiguity and risk-taking in research. In response to the context above and Utterback's challenge, this paper proposes Massive Online Open Research (MOOR) as a better way to deal with such problems. In terms of organization, this paper includes a literature review focusing on wicked problems, crowdsourcing, open innovation and online collaboration. Selected open online research initiatives were used to contextualize the literature review. Based on the literature review and real cases, a MOOR framework was presented and discussed. Limitations and opportunities for future research were also included.

II. LITERATURE REVIEW

In our professional education (and as part of the ethos of many professions) there is a belief on our unrestricted capability to transform a situation into an ideal (perfect) version. Moreover, during the industrial age we learned we could not only produce these ideal outcomes, but we had to do it using the least amount of resources possible [1]. The authors went to say problem-solving becomes about planning and designing problem-solution studies and experts are then in charge of diagnosing and finding solutions amid a finite and clearly identified alternatives while optimizing the utilization of resources. Despite its industrial age origins, this is still the dominant approach to problem-solving in the 21st century. However, it becomes increasingly clear it is no longer adequate to most of our most pressing societal and environmental problems [1, 9, 2, 5].

This scientific, mechanist approach to problem-solving is adequate to deal with tame or benign problems. Tame problems are those with a clear mission, expected outcomes and clearly defined success criteria [1]. Even very complex problems (e.g., safely sending a crew to the moon and back) fit this categorization, but there is the case of wicked problems as defined as follows by [1].

1. There is no definitive formulation of wicked problem;
2. Wicked problems have no stopping rule;

3. Solutions to wicked problems are not true-false, but good-or-bad;
4. There is no immediate and no ultimate test of a solution to a wicked problem;
5. Every solution to a wicked problem is a "one-shot operation"; because there is no opportunity to learn by trial-and-error, very attempt counts significantly;
6. Wicked problems do not have an enumerable (or an exhaustive describable) set of potential solutions, nor is there a well-described set of permissible operations that may be incorporated into the plan;
7. Every wicked problem is essentially unique;
8. Every wicked problem can be considered to be a symptom of another problem;
9. The existence of discrepancy representing a wicked problem can be explained in numerous ways. The choice determines the nature of the problem's resolution;
10. The planner has no right to be wrong.

Roberts [9] elaborated on that and provided us with a way of navigating the different categories of problems. Figure 1 is an attempt to synthesize Roberts' ideas.

In this paper we are particularly interested in wicked problems addressed by collaborative strategies. In this line of thought, source [7]mentioned a new era of cross sector collaboration due to the fact that shared value creation requires new forms of collaboration. Perhaps, beyond trans-disciplinarily problems should be approached from multiple perspectives, but without the labelling or specific mindset of any discipline [10]. Porter and Kramer [11]proposed the creation of shared value as much more effective than corporate social responsibility. Source [12] claimed partners want to keep their autonomy; therefore trust is a key element in sharing knowledge and experience while source [13] stated these new models of collaboration can mitigate potential animosity amid partners. Based on various initiatives and community and social initiatives, source [14] proposed the idea of going beyond problem-solving to focus on strength-based approach. The authors proposed four characteristics of a strength-based approach (i.e., shared purpose, shared effort, shared identify and shared ownership). To follow-up with the theme we now review the literature on crowdsourcing.

The first mention to crowdsourcing was made by Howe and Robinson [15]. The authors proposed it as an even cheaper and much more effective alternative to outsourcing. In summary, crowdsourcing is about harnessing creative solutions from a distributed network of individuals, based on an open call for proposals [16]. The theory of collective intelligence proposed by Levy and Bonomo [17] helps explaining how a process like that may be more effective than an automated or outsourced one. The authors defined collective intelligence as a "Form of universally distributed intelligence, constantly enhanced, coordinated in real time, and resulting in an effective mobilization of skills (p.13). Source [18], in a slightly different approach, based on a number of different cases, went to say large number of individuals can effectively solve problems. Ultimately, Kitur et al [19]claimed crowdsourcing is a powerful mechanism for accomplishing complex work online. The author's refer to Amazon's Mechanical Turk [20] a platform in which the company is able to post a large number of very diverse tasks to be completed by an even larger network of independent workers. The secret of the success becomes to define those tasks into small, self-contained tasks. This idea takes division of Labour concept from the Industrial Revolution to a much higher level. Figure 2 is a summary of the process:

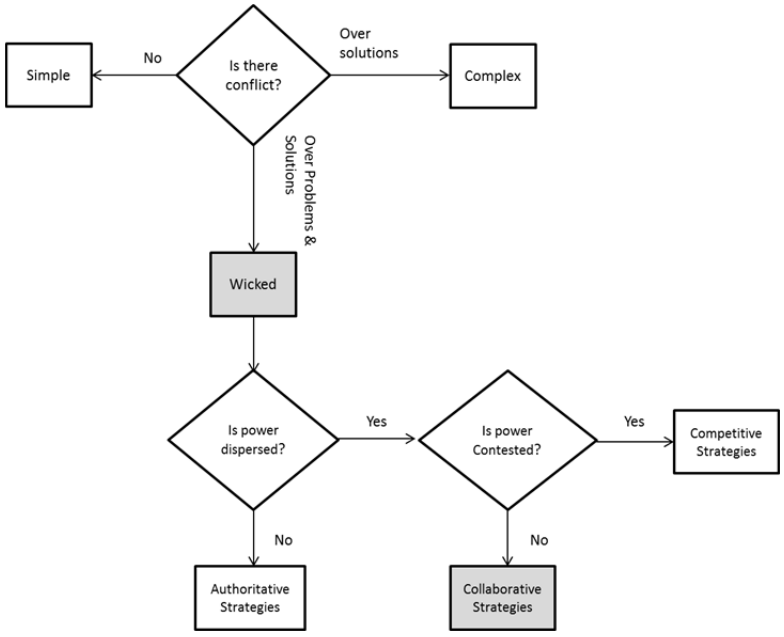

Figure 1: Coping Strategies to Deal with Wicked Problems

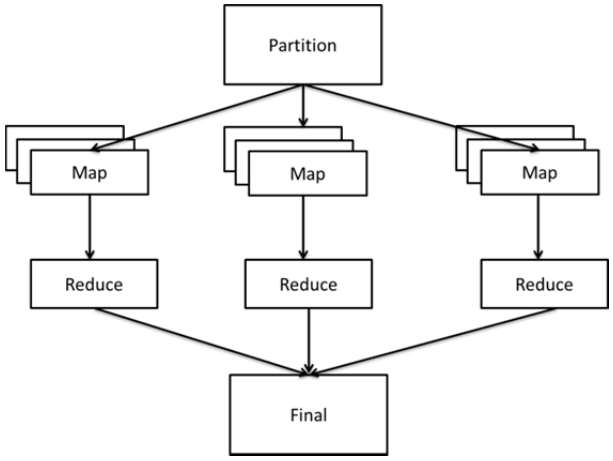

Figure 2: M-Turk, Based on Kittur et al 2011 [19]

In brief, during the Partition phase large tasks are broken down into a large number of small ones. Small tasks are then completed during the Map phase. The Reduce phase is about assembling the small tasks back together to compose a solution at the Final phase. The process works fairly well with complex tasks, but the challenge becomes how to breakdown complex work in small, limited online tasks. Another, challenge comes from the fact that crowdsourcing is an open, distributed problem-solving model, but normally not open source [16]. Companies contract the services and own the solutions. More specifically, the challenge is how to manage trust and self-interest in a General Public License (GPL) and / or Lesser General Public License context. A final challenge comes from the idea of complex problems being tame and the problems we are trying to address in this paper being wicked. There is an important gap in the literature yet to be addressed.

III. CASES

In their ground-breaking book [21] proposed a "new era" of participation in which individuals would no longer be restricted by a limited set of economic roles, geographic barriers. The authors called for advent of mass collaboration fuelled by ever-lowering communication costs and the developing of new mindsets. Based on exhaustive research, considering those born between 1982 and 2000, Howe & Strauss [22]coined the term Millennials. According to the authors the Millennials tend to be more upbeat, team-oriented, and confident [22]. Drawing conclusions from an 11,000 people global survey, source [23] provided another influential view of more or less the same generation. The author called them the Net Generation (NetGens). According to [23], NetGens are able to multitask better for having better switching capabilities and larger working memory. In a more recent work, source [24] agreed and added "Millennials will carve out fresh concepts of public cyberspace and use information to empower groups rather than individuals". They also tend not be consumers of information, but rather prefer to be part of the creation process [25]. They are able to dedicate a large amount effort and focus on things that from a values perspective are dear to them. Combining findings from sources [22, 24] and sources [23, 25] we have a very different picture than that of individuals from previous generations and consequently there are profound impacts on the way work is done. For instance, online collaboration tools have been used to enhance intra-organizational communication and collaboration [26]. This research interest is supported also on the practical level. Atos, the leading information technology service company with over 70000 employees, has utilized Zero-email –initiative that targeted significant reduction of internal emails and utilization of online collaboration tools instead. However, adoption of these communal practices requires responsibility for each organizational member. Therefore it is crucial for the organization success that each organizational member is aware of the management's drivers for adoption [27]. That reflects on the importance of identifying various drivers among organizational members and in particularly among senior management. However, new working practices are suggested to challenge traditional practices even though these working practices might not be new to all organizational members. Result-driven and task oriented generation of digital natives [28] won't need to consider any change in the way of working, as they are used to communal working practices. Nevertheless, these communal working practices are based on trust [28]

Issues of trust have been identified as one of the main challenges for online collaboration [29, 30, 31, 32]. Trust can be addressed from several perspectives. There should be trust between employee and manager (intra-organizational trust) [28] but also within a project team [29]. Another important issue in the case of virtual collaboration is the need for shared purpose [31, 32, 33] In case of the project team includes external parties it can be addressed in terms of open innovation [34]. It is also true to truly considering innovation as an open system unilateral, discipline-based approaches must be abandoned to enable multi-perspective approaches that cannot be labelled within boundaries of bodies of knowledge [35]. Opening the innovation to several parties challenges the whole innovation process as there might be not-invented-here and not-shared-here syndromes [36]. Nevertheless, benefits of more open innovation can be even bigger than possible challenges, at least in some cases [37].

Communal working and collaboration done by intrinsic motivated volunteers have been happening since 90´s. The Linux open source ecosystem is a good example of that. Information and communication (ICT) - based innovations have enabled an intensive and extensive use of online collaboration. This boom of global online collaboration and a switch in mindset sparked many examples found on (Table 1). Such cases are no longer restricted to the software realm rather expanding to almost every area of human activity (e.g., community, education, entertainment, government, health and product development).

TABLE 1: EXAMPLES OF OPEN COLLABORATION

Example	Theme/target	reference
Community		
Neighbor for Neighbor	Community engagement, platform for collaboration	[14] http://neighborsforneighbors.org/
Institute for Emerging Issues (North Carolina)	Solve emerging problems affecting communities by sharing data, ideas, and success stories.	[14] http://iei.ncsu.edu/
Education		
Wikipedia	Free encyclopedia for all	www.wikipedia.com
ReCaptcha	Digitalizing books	[38] http://www.google.com/recaptcha/learnmore
DuoLingo	Translating the Web / Learning Languages	[39] http://www.duolingo.com/
Quanta	Science education / basic research	https://quanta.asu.edu/
UC San Diego Bioinformatics	Bioinformatics education / research	https://www.coursera.org/course/bioinformatics
Enterprise driven initiative		
Zero-email	Decrease amount of internal emails	http://atos.net/en-us/home/we-are/zero-email.html
Entertainment		
Star Wreck -movie	Using community to help the production	http://www.starwreck.com/
Funding		
Kickstarter	Crowd funding for new projects and startups	https://www.kickstarter.com/
scikick	Crowd funding for scientific projects	http://scikick.org/
Hardware / Equipment		
Open Source Ecology	Open-source hardware equipment for farming	http://opensourceecology.org/
Arduino	Open-source electronic prototyping platform	http://arduino.cc/
Healthcare		
Medting Solution	Online collaboration between doctors	http://www.medicalexchangemedting.com/
Public sector		
Challenge.gov	Crowd source challenges and solutions in public sector	Mergel & deSouza [40] https://challenge.gov/
Research		
Research Gate	Allowing researchers to share their publications and ongoing research to facilitate the development of collaboration	http://www.researchgate.net/
Software		
Linux	Develop open-source operating system	Awazu & deSouza [41] http://www.linux.com/
VLC Player	Develop open-source video player	http://www.videolan.org/vlc/
Hadoop	Open-source software framework for addressing big data	http://hadoop.apache.org/

IV. MASSIVE ONLINE OPEN RESEARCH FRAMEWORK (MOOR)

During a keynote delivery during PICMET 2013, Francoise D. Roure [42] call for the need of massive online open research to address challenging technology-related problems. A follow-up Internet research found Quanta, a new online research program that harnesses social networking and e-learning to connect high school students with Arizona State University Researchers. Quanta claims to be a MOOR platform [43]. Pavel Pevzner and Phillip E. C. Compeau with the University of California San Diego launched a Bioinformatics online course on Coursera – online platform for open courses, in which students learn the topics with the help of an algorithm and engaging in real research coordinated by UC San Diego researchers [44]. The University and Wikipedia [45] called it Massive Online Open Research. Wikipedia also refers to Research Gate, as a MOOR. Research Gate was initiated in 2008 in Germany and currently counts with some 3 million scientists scattered world-wide sharing publications, on-going research, finding complementary pieces of research and developing collaboration opportunities [46]. Carlos Palma and Esteban Pacheco launched in October of 2013 a fundraising campaign to build scikick.org as a platform to facilitate funding and supporting MOOR – like initiatives. Quanta, UC San Diego, Research gate and Scikick in particular are clear indication of a trend yet they don't fully represent the potential for MOOR. Rather than providing a definition for MOOR, we will propose a conceptual framework to help further the discussion and contribute to bring the idea to fruition. Figure 3 illustrate the relationship between those dimensions.

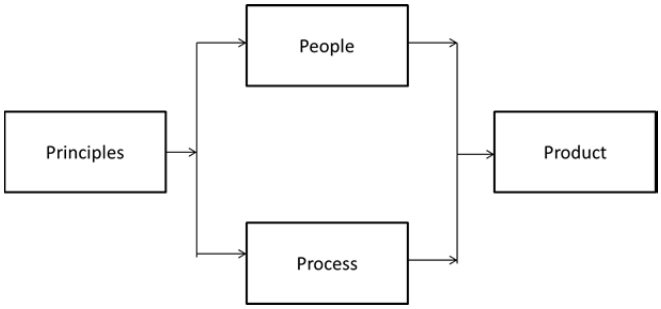

Figure 3: The Four P of Massive Online Open Research

A. Principles:

First, there should be a culture of openness, autonomy and self-regulation. Individuals feel free to collaborate in whatever way they can and should be in charge of managing their own progress. Second, there should be a deep sense of shared purpose. This higher purpose should drive and motivate people's achievement in line with the first principles. Third, any initiative or project pursued the MOOR framework in mind should be guided not only by an open innovation approach, but also by an open source, non-proprietary approach. Problems mitigated by and innovation originated from the MOOR framework should aim at benefiting society as a whole. Deriving from the previous principles there should be an environment of trust, in which knowledge sharing is the norm. The majority of the examples mentioned on Table 1 display such principles. Wikipedia, Linux, Hadoop, Duolingo and Arduino are textbook cases, so are initiatives like Medting. Medting is essentially a web-based platform in which medical doctors share knowledge, work collaboratively in cases and are even able to look for a second opinion. Despite the apparent competitive world of medical practice, a large community of physicians quickly realized how much better they could perform and how much more they could accomplish by collaborating with each other.

B. Process

First, the ideal media or *locus* for the MOOR process to occur is the World-Wide-Web. More specifically, the process is envisioned to run on a social media like platform. Second, communities and society in general should trigger the process. Practically speaking, the process starts with people sharing their emerging problems, issues, needs, concerns and also insights and nuances about them. For instance, problems and issues (or the symptoms shared by community members) setup themes for MOOR to address. Eventually, well-known environmental or social problems (e.g., clean energy, homelessness) are naturally taken as themes. Third, interested researchers, practitioners, in essence specialists in the field, build their profiles, shared their research / work interests, results and ongoing research /work. These specialists find context for their work and chance to make a real contribution, but also find people with complementary or overlapping interests. Multi-partner collaboration is expected to sprout from the process as ad-hoc world-wide research teams emerge. Fourth, some of those research teams will able to promptly address some of the themes by combining existing expertise and technological solutions. In some cases a gap in the current state-of-the-art will be revealed. Ad-hoc research teams will then form to push the limits of the fields. Furthermore, some research teams will be working on scaling-up effective local solutions for problems found elsewhere in the world. Fifth, either in the case of using a combination of existing solutions or developing new ones, this self-assigned, autonomous, ad-hoc research teams will employ a map reduce approach to assign tasks back to the online community. This supposedly vast online community will be able quickly complete time-consuming tasks (e.g., bibliography review). Based on idea of collective intelligence, the community will also solve tasks that are more sensitive, depending on pattern-detection or sense-making. In brief, the community will solve problems thus far computers struggle to solve. Some of those tasks can be pursued as educational assignments (graduate, college or K-12). Sixth, Ad-hoc research teams will take the result from the map reduce process and collaboratively build into best possible solutions. Those solutions will be made available to the community and could be again used as trigger for future cycles or combined with other solutions in future cycles. In the case of new technologies all new developments will be treated within the scope of a General Public License (GPL). Documents, publications and research results, will fall within the scope of Creative Commons. This proposed process is perhaps the most synthetic aspect of the whole paper. Consequently, not a single example would match it in details. However, each initiative mentioned in this paper could be used to demonstrate parts of the process. For instance, the Institute for Emerging Issues (North Carolina) is a great example of how community engagement could work as the trigger for the process. The Institute is also a good example of an open, collaborative approach being better to deal with hard-to-define problems, sometimes controversial problems (i.e., wicked). Moreover, Quanta and UC Davis Bioinformatics course on Coursera are good examples of employing a large network of individuals with multiple levels of expertise (K-12, undergraduate, graduate) to solve real scientific problems. In another example, Research Gate could serve to demonstrate the type of platform which could gather a world-wide, diverse network of researchers. Finally, the majority of the examples mentioned on Table 1 result in non-proprietary solutions with the potential to solve or mitigate problems and issues benefiting society as whole.

C. People

The first aspect to outline is diversity. In this case, diversity should come from a variety of perspectives. The scientific community as well as practitioners should be represented. Society's various ways of living and social classes should also participate. Multiple levels of expertise are expected. Experts in the field, graduate, college and K-12

students alike are expected to play a role as they all offer unique perspectives. Diversity should also be generated by making sure the community is truly global from the rural Northern Canada to Melbourne financial district. Positive local perspectives through local stories can be made global while global trends can help local communities. The second aspect is a about pure motivation to generate positive change; people will be essentially volunteering their time. The community should come together operating in synch with a high level of shared purpose and trust. Share purpose and trust will help them to engage in a genuine process of collective knowledge creation. In such cases the reward mechanism should be intrinsic. Nevertheless, being part of a global effort that generates positive change is naturally desirable. Most examples provided within this paper represent the type of initiative in which a large, diverse network of self-motivated individuals collaborates to deliver widely beneficial results. As a matter of fact, there is no argument against the way Linux challenges the multibillion-dollar, centralized and proprietary approach Microsoft has to software development. There is neither an argument against the idea of Hadoop and Big Data are changing the competitive landscape in many industries. Duolingo on the surface is an interactive, fun and free way of learning a new language. Internally, it is a collaborative effort to translate massive amounts of web content available online in English to other languages. Duolingo does a better job at translating the web then any natural language – based system. The platform is also faster and incredibly more cost effective than an actual translation effort done by professionals. These MOOR like initiatives are being used to tackle highly complex yet poorly defined problems (i.e., high-tech new product development).

D. Product

MOOR is expected increase level of ingenuity of solutions when compared to unilateral, discipline-based, proprietary solutions. Linux and Hadoop platforms are strong indications of what is possible, although limited to a very particular field – software development. MOOR is also expected to scale-up the success of local solutions to address similar problems world-wide, thus helping addressing challenging global issues like the need for clean energy sources or affordable yet sustainable shelter. Open source platforms like Arduino provide a great model for future projects and are also a very good starting point for many. Finally, the MOOR framework is expected to magnify our capacity to generate new knowledge and further our understanding of the many bodies of knowledge. In the process of increasing the yield of our scientific production, MOOR will also help us re-evaluate the way we think about science, scientific production and performance of researchers and research organizations. Hopefully, the number of scientific papers in high-impact journals and patents will no longer be the most important aspect to consider for the scientific community, but real improvements in society will. Initiatives like Wikipedia, Duolingo and Arduino are remarkable but likely the initial, clumsy steps into this direction.

V. CONCLUSION

We started this paper talking about the need for a different approach to tackle wicked problems. As reported throughout the article, there is a new type of mindset developing. A massive network of people voluntarily comes together, collaborates, and develops something amazing. Then, instead of patenting and exploiting its benefits, the network gives it back to society to use and further develop it. The examples discussed in this paper not only demonstrated the open research idea is possible, but they are a clear indication of things to come. Each of the examples is somewhat idiosyncratic and focused on more specific themes, but they each contribute with novel principles, processes, attitudes & behaviors and outcomes that are in fact successful. None of the examples provided in the paper perfectly match the framework; that is natural. However, each case illustrates several aspects of it corroborating with its potential. The major contribution of this paper is to try to come up with a conceptual framework based on the examples and pertinent literature. This framework is a more cogent step forward on the study of mass collaboration and open source initiatives. Consequently, this framework is expected to spark a discussion around the theme and ultimately enable further development of the idea into a working model. A more practical contribution of this paper is to influence practitioners involved in fields like social security, environmental protection and public healthcare to consider alternate ways to investigate and mitigate problems.

The limitations of this paper are also opportunities for future research. Future research should focus on further developing the theoretical background supporting the conceptual model. A specific development should include a review of the increasing body of knowledge on social innovation and social entrepreneurship. Another could be an in-depth look into the dynamics of knowledge creation / generation leading to innovation within the model. A final future development is to validate the conceptual model employing a multiple case-study. A robust analysis of such case-study would ultimately help developing a working model for the theory. Such working model will have the potential to be applied to mitigate a variety of problems / issues, ultimately wicked problems, which are currently unsuccessfully addressed by traditional problem-solving approaches.

REFERENCES

[1] H. Rittel and M. Webber, "Dilemmas in a General Theory of Planning," *Policy Sciences,* vol. 4, no. 2, pp. 155-169, 1973.

[2] V. Brown, P. Deane, J. Harris and J. Russel, Tackling Wicked Problems: Toward a Just and Sustainable Future., London: Earthscan, 2010.

[3] J. Martin, Martin, James. The meaning of the 21st century: A vital blueprint for ensuring our future., Sydney: Random House, 2007.

[4] F. Westley and N. Antadze, "Making A Diference: Strategies for Scalling Up Social Innovation," *The Public Sector Innovation Journal,* vol. 15, no. 2, pp. 2-19, 2010.

[5] J. Kolko, Wicked Problems Worth Solving, Austin: Austin Center for Design (AC4D), 2012.

[6] R. Buchanan, "Wicked Problems in Design Thinking," *Design Issues,* vol. 8, no. 2, pp. 5-21, 1992.

[7] A.-D. Lu, "Harnessing Social Innovation Through Inclusive Thinking," *Japan Social Innovation Journal,* vol. 3, no. 1, pp. 56-61, 2013.

[8] J. Utterback, "Explorations in Technology, Innovation and Entrepreneurship," in *Portland International Conference on Engineering and Technology Management*, San Jose, California, 2013.

[9] N. Roberts, "Wicked Problems and Network Approaches to Resolution," *International Public Management Review,* vol. 1, no. 1, pp. 1-19, 2000.

[10] G. Verghese and M. Machado, "Undiscipline the Disciplines: Towards Collective Engament," in *8th International Conference on Design Principles and Practices*, Vancouver, 2014.

[11] M. Porter and M. Kramer, "Creating Shared Value: How to Reivent Capitalism - And Unleash a Wave of Innovation and Growth," *Harvard Business Review,* pp. 2-17, 2011.

[12] D. Harisson, N. Chaari and M. Comeau-Vallee, "Intersectoral Alliance and Social Innovation: When Corporations Meet Civil Society," *Annals of Public And Cooperative Economics,* vol. 83, no. 1, pp. 1-24, 2012.

[13] J. A. Phills, K. Deiglmeier and D. T. & Miller, "Rediscovering social innovation," *Stanford Social Innovation Review,* vol. 6, no. 4, pp. 34-43, 2008.

[14] A. Howard and K. Southwell, "Community Experience Design: Bringing People Together to do Great Things," in *Design Principles and Practices: Design as Collective Intelligence*, Vancouver, 2014.

[15] J. Howe and M. Robinson, "The Rise of Crowdsourcing," 14 June 2006. [Online]. Available: http://www.wired.com/wired/archive/14.06/crowds.html. [Accessed 30 December 2013].

[16] D. Brabham, "Crowd-Sourcing as a Model for Problem Solving: An Introduction and Cases," *The International Journal of Research in New Media Technologies,* vol. 14, no. 1, pp. 75-90, 2008.

[17] P. Lévy and R. Bonomo, Collective intelligence: Mankind's Emerging World in Cyberspace, New York: Perseus Publishing, 1999.

[18] J. Surowiecki, The Wisdom of the Crowds, New York: Anchor Books, 2004.

[19] A. Kittur, B. Smus, S. Khamkar and R. Kraut, "CrowdForge: Crowdsourcing Complex Work," in *24th Annual Symposium on User Interface Software and Technology*, Santa Barbara, CA, 2011.

[20] Amazon Inc., "Mechanical Turk," 6 January 2014. [Online]. Available: https://www.mturk.com/mturk/. [Accessed 6 January 2014].

[21] D. Tapscott and A. Williams, Wikinomics: How Mass Collaboration Changes Everything, New York: Penguin Group, 2006.

[22] N. Howe and W. Strauss, Millenials Rising: The Next Great Generation., New York: Vintage Books, 2000.

[23] D. Tapscott, Growing Up Digital: The Rise of the Net Generation., New York: McGraw-Hill., 1998.

[24] N. Howe and W. Strauss, "The Next 20 Years: How Customer and Workforce Attitudes Will Evolve.," *Harvard Busines Review,* vol. 85, no. 8, pp. 41-52, 2007.

[25] D. Tapscott, Grown Up Digital: How the Net Generation is Changing Your World, New York: McGra-Hill, 2009.

[26] T. Peltola and S. J. Makinen, "Improving absorptive capacity in product development with online collaboration tools.," in *PICMET 2013 (Technology Management in the IT-Driven Services)*, San Jose CA, 2013.

[27] A. L. D. A. Burcharth, M. P. Knudsen and H. A. & Søndergaard, "Neither invented nor shared here: The impact and management of attitudes for the adoption of open innovation practices.," *Technovation (In Press),* 2014.

[28] K. Bondar and T. Peltola, "Emergent working practices: Cases from knowledge-based organizations.," in *European Academy of Management (EURAM)*, Instanbul, 2013.

[29] H. Haapasalo and P. Lohikoski, "Virtual Competencies and Knowledge Transfer in Global NPD: A Case Study.," *International Journal of Management, Knowledge and Learning,* vol. 2, no. 2, pp. 185-207, 2013.

[30] M. Machado, "Educating Social Managers: A Social Networking Approach to Management Education," *International Journal of Management Education,* vol. 2, no. 1, 2013.

[31] M. Machado, "Systemic Innovation Capability: The Case of Embraer, the Brazilian Aircraft Manufactuer," in *Knowledge and Technology in Virtual Organizations*, Hershey PA, Idea Group Publishing, 2007, pp. 220-239.

[32] M. Machado, "Systemic Innovation Capability: The Ultimate Competitive Advantage of Early Technological Followers," in *Portland International Conference on Management of Engineering and Technology (PICMET)* , Portland OR, 2009.

[33] M. Machado, "Global Knowledge Networking for Innovation: A Case Study of Embraer," *Knowledge Management Professional Society Journal,* vol. 2, no. 1, pp. 22-30, 2005.

[34] H. W. Chesbrough, Open innovation: The new imperative for creating and profiting from technology., Boston: Harvar Business Press, 2003.

[35] G. Verghese and M. Machado, "Un-Disciplining the Disciplines: Towards Collective Engagement," in *Eighth International Conference on Design Principles and Practices: Design as Collective Intelligence*, Vancouver, Canada, 2014.

[36] A. L. d. A. Burcharth, M. P. Knudsen and H. A. Søndergaard, "Neither invented nor shared here: The impact and management of attitudes for the adoption of open innovation practices," *Technovation (in Printing),* 2014.

[37] H. Chesbrough, "The logic of open innovation: managing intellectual property," *California Management Review,* vol. 45, no. 3, pp. 33-48, 2003.

[38] L. Von Ahn, B. Maurer, C. McMillen, D. Abraham and M. Blum, "Recaptcha: Human-based character recognition via web security measures," *Science,* pp. 1465-1468., 2008.

[39] L. von Ahn, "Duolingo: learn a language for free while helping to translate the web," in *International Conference on Intelligent User Interfaces*, Santa Monica, 2013.

[40] I. Mergel and K. C. Desouza, "Implementing open innovation in the public sector: The case of challenge.gov," *Public Administration Review,* vol. 73, no. 6, pp. 882-890, 2013.

[41] Y. Awazu and K. C. Desouza, "Open knowledge management: Lessons from the open source revolution," *Journal of the American Society for Information Science and Technology,* vol. 55, no. 11, pp. 1016-1019, 2004.

[42] F. Roure, "Managing Immersive Technology: A Shared Responsibility," in *Portland International Conference on Engineering and Technology Management*, San Jose CA, 2013.

[43] Arizona State University, "Quanta," 13 October 2013. [Online]. Available: https://asunews.asu.edu/20131015-quanta-launch. [Accessed 21 January 2014].

[44] UC San Diego, "Bioinformatics," September 2013. [Online]. Available: https://www.coursera.org/course/bioinformatics. [Accessed 26 January 2014].

[45] Wikipedia, "Massive Online Open Research," 15 November 2013. [Online]. Available: http://en.wikipedia.org/wiki/Massive_online_open_research. [Accessed 21 January 2014].

[46] Research Gate GmBh, "About Us," 21 January 2014. [Online]. Available: http://www.researchgate.net/aboutus.AboutUs.html. [Accessed 2014 January 2014].

[47] SciKick, "Index," October 2013. [Online]. Available: http://scikick.org/index.html. [Accessed 21 January 2014].