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A Case Study on the Adoption of a Digital Data Collection System for Plant Breeding

Simona Lubieniechi, Crystal Chan, Kirstin Bett, Aaron Hertes, Phil Phillips & Peter WB Phillips

This research is undertaken in collaboration with the Johnson Shoyama Centre for the Study of Science and Innovation Policy.

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Abstract

With the rise in interest in curating, linking and using big data for plant breeding, the big question is whether users will come if systems are built. This paper explores the uptake and use of a digital data collection template and of KnowPulse, a platform website hosted at University of Saskatchewan. KnowPulse was designed to provide a one-stop site for genomics and phenomics data and a range of relevant tools for breeders of pulse crops, especially lentil. The paper highlights a host of variables that have limited full uptake and use of this innovative tool.

Acknowledgement

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1. Introduction

It often appears that digitalization is taking place in every aspect of our lives. Virtual assistants are in our homes upon demand to play music, provide real-time information, and help with minor chores. Robotics and artificial intelligence slowly infiltrate our workplace as jobs are being automated. Every organization endlessly talks about implementing digital technologies as a mean to improve service efficiency and quality. Digitalization is in our mind – if it is not constantly in our face. Nevertheless, there are instances where we wish digitalization had become the standard already, but it is not. Plant breeding is one of those instances.

In a breeding program, the breeder makes crosses and selects the progeny (offspring) that carry desirable traits. Selection decisions are made based on the results of a series of field experiments that are conducted in different environments over several years. Each of the field experiments easily contains hundreds to thousands of unique samples. Over time, the volume of these observational data multiplies and the need to organize becomes apparent. The emergence of high-throughput genomic sequencing and field imaging technologies only adds to the pressure to digitalize. More data will always help breeders in their decision-making process, but only if they can navigate and make sense of such massive volume of data.

In an ideal setting, all data associated with the plant of interest should be readily accessible to the researcher regardless of their physical location. Genotypic data and advanced phenotypic data are typically generated as an electronic file, which makes storing and sorting of the data relatively straightforward. Observational data from field experiments, however, have traditionally been done manually using pencil and paper (known as field notes). The drawbacks of a manual data collection system are evident. In this "digital age", everyone would wholeheartedly agree that digitalizing the field data collection process makes a lot of sense.

Considerable efforts have been made in this respect. Field Book, developed under the One Handheld Per Breeder Initiative, is an open-source application for electronic data capture from field experiments that runs on consumer-grade Android tablets (Rife and Poland [2015]). Originated as a project under the CGIAR (formerly the Consultative Group for International Agricultural Research) program in 2010, the Integrated Breeding Platform (IBP) offers the Breeding Management System - a suite of computer applications that help support field research data management and accelerate cultivar development. In 2016, CGIAR rolled out the Excellence in Breeding platform that seeks to "provide a single solution… so that the entire breeding data workflow … can be accessed from a single user-friendly dashboard"[1]. Sadly, many scientists and breeders continue to record data on paper and then transcribe the notes into a digital file post-facto. Within public research and breeding programs, the way field data are collected has changed very little since Gregor Mendel studied hereditary with his garden peas in the 1800s.

Although implausible and counter-intuitive, even highly educated scientific experts avoid or postpone implementation of innovations (Clyne et al., 2017). From the management's perspective, innovation implementation often ends upon announcing the availability of said innovation to staff.

[1] https://excellenceinbreeding.org/blog/toward-unified-breeding-data-management-system

But, in effect the organization is simply introducing an innovation. Innovation implementation does not occur until said innovation is consistently used within the organization (Klein and Sorra, 1996; Kim and Chang, 2017), and the organization benefits from the results of the innovation success (Bhattacherjee, 1998). In most circumstances, innovation fails because of failure to adopt and implement (Klein and Sora, 1996; Klein and Knight, 2005) – and our AGILE (Application of Genomics to Innovation in the Lentil Economy) project contains one of the many “failure to implement” stories.

2. The AGILE Case

The Application of Genomic Innovation in the Lentil Economy (AGILE) project was a genomics-based research project funded by Genome Canada in the 2014 Large-Scale Applied Research Project Competition entitled Genomics and Feeding the Future. One of the goals within the AGILE project was to characterize a diverse collection of lentils to determine the genetics underlying the differences in their ability to grow well in different parts of the world. Field trialing of this global collection of lentils (324 varieties to be exact) was performed in Canada, United States, Spain, Italy, Morocco, Bangladesh, India, and Nepal for at least two growing seasons. To standardize the field phenotyping process, all researchers involved were provided a data collection template (a MS Excel spreadsheet) pre-loaded on an Android tablet. They were then asked to upload the data files onto a secure module in the Knowpulse web portal (hosted by the lead institution in Canada), using a drag-and-drop procedure. Users were also given the option to back up their data during the season using the same module. Instructional videos were sent to the researchers just prior to the beginning of field trials.

The Knowpulse development team was under the impression that uploading an Excel spreadsheet to a website is a “no-brainer”. Researchers should be able to make the digital transition easily as they are already familiar with the Microsoft programs and mobile devices. Sadly, the digital data collection system turned out to be a bit of a disappointment. Aside from the lead institution, only one international researcher used the tablet and the web portal field data module as anticipated. A majority of the researchers decided not to use the tablet and continued to forward the data via email months after the field trial was completed.

Such failure prompted us to investigate the dynamics within the international research team when it comes to technology implementation. Specifically, we conducted a three-part survey and a face-to-face semi-structured interview with 11 researchers from eight countries in the summer of 2017. This study is important not only to help the development team improve this digital data collection system going forward, but also to better understand barriers to innovation implementation within an international team – which is typically the norm when it comes to large-scale research and development projects these days.

2.1 The role of the behavioural intentions and facilitating conditions in tech adoption

The barriers to innovation implementation have been extensively studied in the past and several models have been developed to help understand the gap between introducing an innovation and bringing said innovation into practice. For this study, we used the Unified Theory of Acceptance and Use of Technology (UTAUT) as the theoretical framework to build the survey questions and analyze the results. Developed by Venkatesh *et al.* (2003), UTAUT predicts user adoption in information systems and information technology innovations. It identifies behavioural intentions and facilitating conditions as two direct determinants of an individual's use behaviour.

Behavioural intentions are comprised of the following components:

- Performance expectancy – Does the innovation make it easier to do my job and/or help me to do my job better?
- Effort expectancy – How much effort do I have to put in to master the use of this innovation?
- Social influence – How important it is for me to be seen using this innovation within the team/organization?

On the other hand, facilitating conditions refer to the users' perception of the existing organizational and technical infrastructures that support the use of the innovation, which include policies such as the provision of the relevant resources, training, and technical assistance, and the degree to which the innovation is compatible with existing technologies and practices. The objective quality of these conditions is irrelevant. When the users see the facilitating conditions to be lacking, they will instinctively resist the implementation process out of dissatisfaction.

In addition, in the survey of our investigators we included questions derived from Rogers' five attributes of innovation (Rogers, 2003) to assess AGILE researchers' perception of the proposed innovation. These attributes are:

- Relative advantage – Is the innovation better than the previous one for me?
- Compatibility – Does using this innovation align with existing customs of my social group or organization?
- Complexity – Is this innovation difficult to understand and/or use for me?
- Trialability – Did I get to experiment with this innovation before I had to use it?
- Observability – Did I witness any benefits when others used this innovation?

The relationship between UTAUT and Rogers' five attributes of innovation diffusion is illustrated in Figure 1.

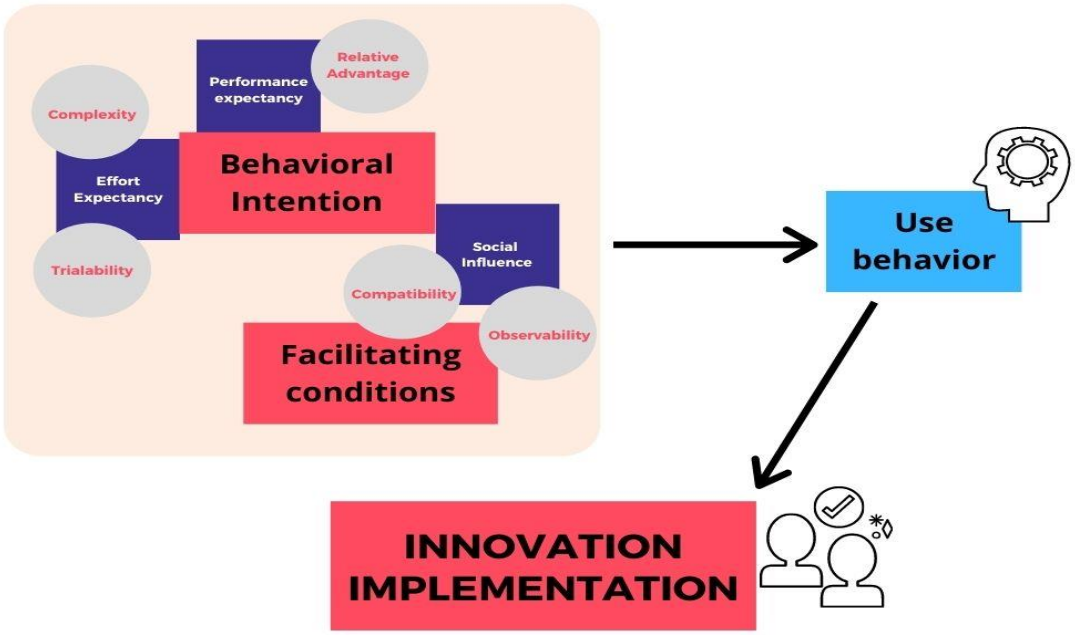

Figure 1. UTAUT and Rogers' five attributes of innovation diffusion

2.2 Survey results on behavioural intentions and facilitating conditions

To the technology developers, the survey results came both as a surprise and as a valuable learning experience. Despite the system being built using well-known interfaces (i.e., MS Excel and a web-based drag-and-drop file upload), researchers still had to adapt to a new data collection routine. Several researchers noted that they could not upload their files because the data were rejected for not conforming to the system's standards. This reflects the difference between research disciplines. Data analysts and curators put accuracy and consistency as top priority, while field researchers would much prefer flexibility and durability. While both disciplines agreed that data verification is a great idea, the standards were deemed by the field researchers to be too stringent and computer-generated error messages unhelpful. As well, Android tablets are not particularly user-friendly in outdoor settings due to environment-related issues such as screen glare and system overheating. All survey respondents expressed their anxiety over potential data loss if they switched to a digital data collection system. This prompted some of them to collect data using both field notes and the tablet. Naturally, the tablet was soon abandoned as the perceived effort outweighed the perceived performance.

Survey respondents also remarked on the lack of consultation while the data collection system was developed. Prior consultations provide people with a sense of ownership over the innovation, which makes it more likely for them to use it. An open group discussion involving both the Knowpulse development team and the field researchers would have helped addressing existing concerns and clarify confusions. These meetings would also have prevented another issue – timing of innovation adoption. Field research is very much time dependent, but the digital data collection system was introduced just when everyone was already busy gearing up for the experiments. During the interviews, a few researchers indicated they had numerous email exchanges with the development team just to fix a few glitches within the system. While these issues were minor in nature, they added to the stress associated with the field experiment setup and were enough to put the researchers off from using the digital system entirely. A majority of survey respondents suggested having a designated person in charge of the digital data collection system in future. This individual would be known to all field researchers at the beginning of the project and be responsible for training and troubleshooting activities throughout the project.

While these suggestions might seem obvious, they are very difficult to be realized in real-life scenarios. Research expenditures are always tightly linked to well-defined activities, and funding agencies are generally not in favor of directing research dollars towards core capacity development and maintenance. As a result, all research personnel are multi-taskers with short attention spans and limited mental bandwidth. It is impracticable for anyone to dedicate themselves to a single component of the project for the entire duration. The transient nature of research projects also adds to the difficulty in sustaining an innovation implementation initiative past the project end date.

Further, our research revealed that a country or institution's socio-economic status has a significant influence on the facilitating conditions of implementation process. In AGILE, several individuals who are responsible for actual data collection confessed that they preferred pen and paper because they were overwhelmed by the accountability of using what they perceived to be an expensive tool out in the field. The lack of funds also deterred some researchers from buying tablet accessories, such as a protective case or a stylus, that would have made data recording on the tablet safer and more efficient.

Switching from pen and paper to a spreadsheet on a tablet might sound very trivial, but it is still a new habit building exercise. As we analyzed researchers' feedback using UTAUT's determinants, we can begin to appreciate why we failed to implement what appeared to be a "simple, quick, and dirty" digital data collection system within a small international research team. Financial constraints and limited, remote technical support considerably hindered the implementation process. Most field researchers perceived the digital data collection system as something that has a steep learning curve yet yields minimal benefits, and therefore most were disinclined to change from their traditional note taking habit.

2.3 Virtual collaborative environment and the role of leadership and archetypes

Many researchers in the past have combined the Unified Theory of Acceptance and Use of Technology (UTAUT) framework and Rogers' five attributes of innovation to evaluate technology implementation success in organizations. In the previous section, we provided an overview of the two conceptual models and illustrated how technology implementation failed in our international lentil project from the perspective of behavioral intentions. In this section, we will explain two other UTAUT components: social influence and facilitating conditions.

Along with performance expectancy and effort expectancy, social influence also predicts an individual's' use behaviour of information technology innovations. As mentioned in the previous section, social influence focuses on how important it is for the individual to be seen using the innovation within the social group or organization (Venkatesh et al. 2003). Like Rogers' (2003) "compatibility" attribute, it refers to the influence of management and coworkers on an individual's activity, and how the use of an innovation relates to an individual's prestige within the organization.

The AGILE project lead expected all field researchers to use the Knowpulse digital data collection system but did not have sufficient authority to make the use mandatory. Therefore, it is up to the team lead at each of the collaborating organizations to use their discretion in implementing the technology. In this case, social influence involved both leadership style and team dynamics.

Individuals in leading positions develop their own leadership style depending on a multitude of factors such as personality, experience, education and organizational culture. A leader could be either transactional or transformational. Transactional leadership is concerned with clarifying followers' roles, providing feedback, and establishing rewards based on followers' material needs and desires to stimulate the required level of performance. Transformational leadership also does these things, but it appeals to followers' higher-level needs, such as personal fulfillment, and instills in followers' the confidence and competence to achieve those needs through charismatic and inspiring leadership, intellectual stimulation, and individualized consideration (Burns 1978, Bass 1985, Bass and Avolio 1990).

In every organization, some individuals seemed to play a more influential and decisive role than others in promoting innovation. Scholars in science and technology studies have categorized these individuals into four key behavioural roles (also known as archetypes) - the Idea Generator, Gatekeeper, Technician, Manager, and Champion (Rhoades, Roberts and Fusfeld, 1978, Chakrabarti and Hauschildt, 1989) (Figure 2). Of course, one person may hold one or more key role at the same time.

The Idea Generator is "the inventor, the entrepreneur, or risk taker" driving innovation uptake. In academia, the Manager and the Idea Generator often overlap. The Manager is defined as an individual who uses their authority to overcome resistance to an innovation. The defining elements of the Manager role are authority and responsibility for the project. As such, they are supposed to use their authority to allocate resources in support of innovation implementation, streamline the overall process by imposing both benefits and sanctions on individuals, and facilitate communication across multiple units within the organization. The Manager exerts both social influence (particularly in settings of mandatory use) and affects the facilitating conditions.

The Technician is defined as the individual responsible for defining the basic performance requirements and specifications of an innovation (Maidique 1980). The Technician is responsible for ensuring an innovation is technically sound, as technical unreliability or unsuitability can be a major barrier to the success of an innovation (Klein and Knight 2005). Technicians influence performance expectancy by ensuring the technical quality of an innovation and facilitating conditions by providing support during the implementation process. Unlike the other roles, it seems that the role of Technician is most effective when combined with other roles such as the Gatekeeper, Manager, or Champion. As we have learned from our results, the other roles are more effective when they are filled by an individual who also has a strong understanding of the technical aspects of an innovation.

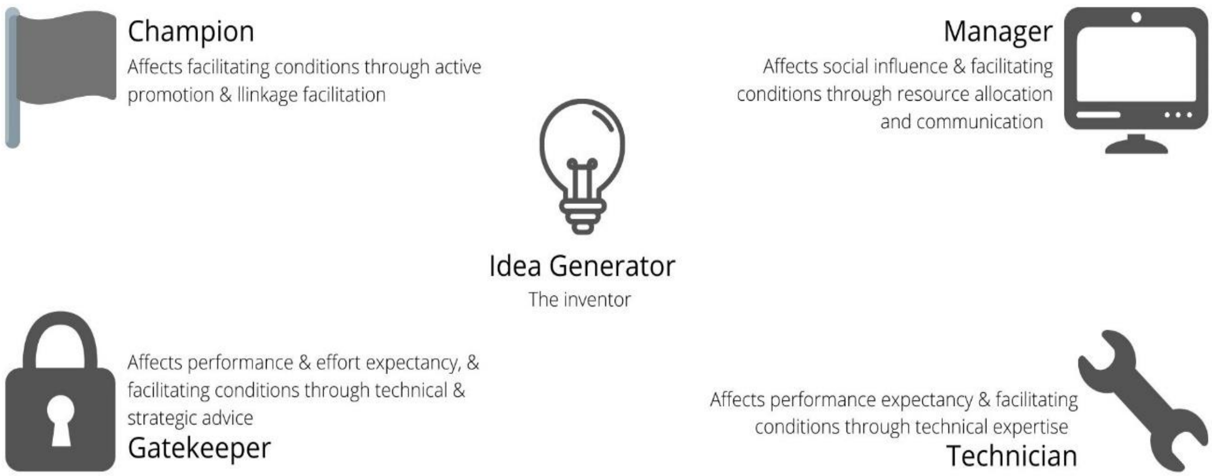

Figure 2. The five archetypes of innovation leadership

The Product Champion is "any individual who made a decisive contribution to the innovation by actively and enthusiastically promoting its progress through critical stages" (Achilladelis, Jervis and Robertson 1971)**.** The Champion plays a linking role and facilitating communication between upper management and technicians (Chakrabarti and Hauschildt, 1989).

One of the major obstacles to the implementation of innovation in the public research space is the ambiguity surrounding "authority" and "hierarchy" within and between organizations. Especially in an academic setting, faculty members often hold both the Idea Generator and the Manager roles. They are responsible for teaching, administrative chores, coordinating various research activities as well as supervising graduate students.

2.4 Observations on collaborative environment and leadership in AGILE

Like all other multi-institutional research project, AGILE did not have a real centralized authority (Figure 3). Neither the project lead nor the project manager would fit into the conventional definition of the Manager archetype. The power of these "Managers" to provide incentives would often end at institutional and cultural boundaries. As discussed in the previous section, research-funding agencies also bring in additional limitations by imposing rules on when and how the research dollar should be spent.

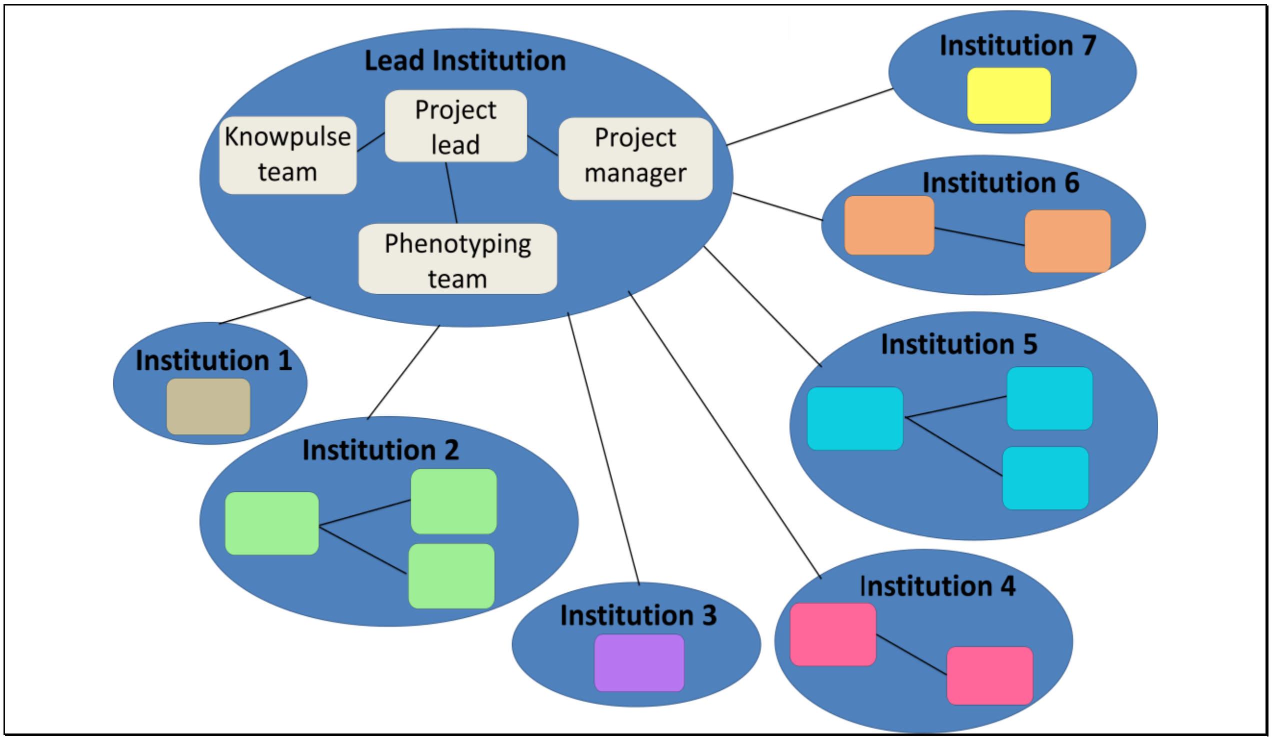

Figure 3. Simplified network diagram for the AGILE project. Each square represents either an individual or a group of individuals performing the same function for the project.

Involving collaborators from multiple countries required that most exchanges be done via the internet. The challenges and intricacy of leading spatially dispersed teams by virtual means have been emphasized by various studies (Purvanova and Bono 2009, Hill and Bartol 2016, Liao 2017). Despite the undisputable advantages such as work hour and location flexibility, reduced operating costs, and the ability to collaborate regardless of geography, it is more challenging to lead virtual teams than face-to-face teams (Liao 2017, Wadsworth and Blanchard, 2015). The lack of face-to-face interaction makes it difficult for leaders to obtain information about team's progress, assert influence over team members, resolve conflicts, or motivate team members (Dulebohn and Hoch, 2017). Virtual team leaders also have to work through social challenges such as team members' isolation, as well as issues concerning building trust and cohesion among team members (Agbi, 2018). Communication in a virtual team is heavily constrained as the lack of verbal and physical cues can lead to reduced shared information among team members, reduced involvement, as well as sense of responsibility (Lilian, 2014). Communication within a team is a key factor, which also encompasses issues such as language proficiency, time zone differences or cultural differences. Together these constraints impair how leaders manage team processes and team dynamics (Hoch and Dulebohn, 2017).

Because research goals in international collaborative projects are achieved primarily through relational governance on a digital platform, we proposed that innovation success is dependent on leadership style and the visibility/accessibility of specific archetype.

For AGILE, complete adoption of the tablet-based digital data collection system occurred when the transformational leader hired a designated person whose work contract highlighted the mandatory use of the new technology system. This person's hierarchical position in the organization placed him as a Gatekeeper, while their personality and attitude towards innovation in general made this person a Champion. This was the most successful combination of leadership and archetypes roles in a team, and it was shown not only by the complete innovation adoption, but also by the team's consistent improvement and reinvention of the new adopted technology. Innovation adoption accelerated when the transformational leader played a Champion role and personally followed all the requirements for using of the new technology. In effect, they became the trailblazer. On the other hand, innovation adoption failed when we had a transactional leader who had a laissez-faire/hands-off attitude towards the way data was recorded and uploaded by their research staff. In turn, the staff had a weak technical understanding and no motivation to use the tablet and the web portal.

As mentioned in the previous section, both the management and technology developers need to be cognizant of the socio-economic disparity within the international research team before introducing any innovation. In AGILE, innovation adoption failed in a team even when there was a transformational leader with bureaucratic influences, but the research staff was too intimidated by the potential cost to use the technology. In one part of the research team, the transformational leader consistently used the tablet for note taking but did not fully adopt the complete set of technologies due to socio-economic limitations and inherent challenges with the tablet itself.

From this case study, we learned that it is important to make the technology developers or the gatekeepers highly visible and accessible within a virtual team to support innovation success. Instead of contacting technology developers directly about their concerns, international team members and leaders usually approached familiar faces such as the project manager or other team leaders. Chaotic communication pathways increased workloads for all and resulted in slow response time to address the issue at hand.

Interview results also showed that having team meetings to discuss plans for technology implementation might improve the social influence determinant. These meetings will prompt the team leaders to devote time and resources to investigate the prescribed digital data collection system themselves. Our results indicated that when team leaders felt more responsible for and were more engaged with technology implementation, they had a higher tendency to require their subordinates to use the technology. As well, the meetings provide a venue for team leaders and team members to share previous experience on digital data recording and sharing. Consultation prior to implementation gets people more invested in implementation success.

We observed several teams and individuals engaging in some degree of reinvention of tablet use, such as using a stylus, adding a carry strap and extra power packs. There was even a case where one individual expanded the system's application and simplified the data collection process for certain traits by attaching a bar-code scanner to the tablet. However, coordinated reinventions between teams were not evident in the project. This resulted in differing degrees of system functionality and, subsequently, different degrees of user satisfaction and adoption. Going forward, we would encourage team members who are more technically competent to be more proactive in communicating their experience, concerns, and reinvention steps. At minimum, this will ensure no one within the team would miss an opportunity to resolve unforeseen difficulties. Project leads would also be better informed of current developments and quicker in authorizing necessary changes.

3. Concluding thoughts

In conclusion, the AGILE case study demonstrated once again that digital technology itself is not the heart of digital transformation. This experience demonstrates there is a multitude of factors to consider before trying to change someone's behaviour towards digital technology – however simple the technology appears. Our observations in general support the UTAUT theory. We also discovered that in virtual teams where goals are achieved in the absence of hierarchy, innovation implementation success depends heavily on leadership style and archetypes roles. Facilitating conditions could be vastly improved by increasing the visibility of the IT team members. Timing of the introduction is also critical when the nature of the work is seasonal – something that technology developers could easily overlook when they are unfamiliar with the field that they are trying to serve. Consultation meetings are therefore critical both to get end-users engaged and to fix obvious blunders prior to implementation.

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