THE ROLE OF EXPECTATIONS IN USER ACCEPTANCE OF UPCOMING TECHNOLOGIES IN EMERGING TECHNOLOGICAL FIELDS

A multiple case study of implementation of upcoming tissue engineering technologies in Dutch health institutions

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Summary

Implementation processes of upcoming technologies in emerging technological fields have proven to be challenging, specifically in technology intensive industries. An important aspect of these implementation processes is user acceptance. Well established models that predict and explain user acceptance are the technology acceptance model (TAM) and the theory of trying (TT). These models, however, lack evidence for the implementation processes of upcoming technologies in emerging technological fields. The first ambition of this research was therefore to test these models in this empirical setting, specifically their concepts of user beliefs.

Through a multiple case study of 11 upcoming tissue engineering technologies in the Netherlands this research was able to determine that user beliefs as proposed by TAM, perceived usefulness and perceived ease-of-use, and TT, internal and external factors to process impediments, are antecedents to technology usage.

To influence implementation processes, however, we need to know on what these user beliefs are based. For established technologies beliefs are traditionally found to be determined by external factors such as objective design characteristics, training, and documentation. However, these external factors are not as readily available when implementing upcoming technologies. It is theorized that expectations can substitute for these information sources through their dictating role in technology development as proposed by the sociology of expectations literature. The second ambition was therefore to explore the role of expectations in the formation of these beliefs.

In the same multiple case study, it was determined that important external factors to the formation of users' beliefs are the application of the technology, its efficacy, the development timeline, and design characteristics. Subsequently, expectations were established to affect the information about efficacy and development timelines of technologies, caused by the actuality of technology developers needing to inflate their reports for the purpose of sustaining their research. As belief formation is contingent on these external factors, expectations were demonstrated to have a possible role in the formation of these beliefs and therefore ultimately in user acceptance.

The results of this research imply that implementers of upcoming technologies in emerging technological fields have another tool in the form of previously developed interventions based on applications of TAM and TT on implementation processes of established technologies. Additionally, it is implied that these implementers should recognize that individual users have their own expectations about the particular implemented technology, and that they should use this knowledge in fostering interventions. Indications for future research directions are also provided.

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1 Introduction

Technological innovations in emerging technological fields are often regarded as potential sources of competitive advantage to firms (Freeman & Soete, 1997; Porter, 1998; Utterback, 1996). Organizations are however known to face difficulties in adopting these new and emerging technologies (Henderson & Clark, 1990; Kimberly & Evanisko, 1981; Tushman & Anderson, 1986). Overall reported failure rates of implementing any type of organizational change are as high as 70 per cent (Balogun & Hope Hailey, 2008; Beer & Nohria, 2000; Burnes, 2004; Paton & McCalman, 2008). The implementation of upcoming technologies in emerging technological fields has also proven to be challenging particularly in several technology intensive industries (Bhattacherjee, 1998; Camarinha-Matos, Tschammer, & Afsarmanesh, 2004; Luo, Li, Zhang, & Shim, 2010; Metzker, 2005). I define these upcoming technologies as technologies that have yet to become widely accepted and used by people and which in some cases may still be subject to further refinement. Implementers of upcoming technologies face difficulties that are in part induced by what is known as the Collingridge-dilemma (Collingridge, 1980): the idea that in the early stages of the development of a technology, the technology is still malleable but its impacts cannot be easily predicted; while in later stages wherein the technology is further developed, more information is available but the technology is now difficult to control and change due it becoming entrenched. In other words, organizations involved in the implementation of upcoming technologies in emerging technological fields are either faced with complexity in determining their actions due to an information problem, or their actions are underwhelming due to a power problem. Because managing actions and decisions of implementation are becoming increasingly important to firm success (Day, Schoemaker, & Gunther, 2004), a large body of literature has been directed to uncover the dynamics of the implementation process (Damschroder et al., 2009; Klein & Knight, 2005).

Implementers of upcoming technologies can be considered to be in the middle of the dilemma, where the technological characteristics are established, but the complementary, supporting factors, e.g., published supporting evidence, institutional support, educational programs, and training standards, are less developed (Al-Senaidi, Lin, & Poirot, 2009; BenMessaoud, Kharrazi, & MacDorman, 2011; Damschroder et al., 2009; Tester & Langridge, 2010). This results in users' uncertainty regarding the appropriateness of implementing the technology. This in turn influences user acceptance of the technology, an important aspect in the implementation process of technologies (Davis, Bagozzi, & Warshaw, 1989; King & He, 2006; Mathieson, 1991; Sheppard, Hartwick, & Warshaw, 1988; Taylor & Todd, 1995). The technology acceptance model (TAM) and the theory of trying (TT) have aimed to explain user acceptance in terms of users' efforts to use and learn-to-use a technology respectively (Bagozzi, Davis, & Warshaw, 1992; Davis et al., 1989). What underlies these theories is the idea that individual behavior is preceded by a behavioral intention, which is based on the individual's attitude towards that behavior, which in turn is based on the beliefs a user holds towards that behavior. This theoretical mechanism of beliefs → attitudes → intentions → behavior is grounded in models from social psychology and has been widely accepted in technology acceptance literature. Unique to TAM and TT are their definitions of user beliefs, regarding the expected consequences of technology usage and expected impediments towards the process of usage respectively. However, while studies using these theoretical frameworks have developed a broad understanding of user beliefs and their influence on user behavior when implementing established technologies, there is a lack of literature explicitly discussing this relationship for implementation processes of upcoming technologies in emerging technological fields. The first ambition of this research is therefore to test the user beliefs as

proposed by TAM and TT for implementation processes involving new and upcoming technologies in emerging technological fields.

Once the representation of user beliefs in the implementation processes of upcoming technologies in emerging technological fields is clear, implementers will need to know what affects these users' beliefs in order to influence user acceptance. Traditionally, beliefs are found to be determined by external factors such as objective design characteristics, training, documentation, others' experiences, and comparable cases (Bagozzi et al., 1992; Davis et al., 1989). However, for upcoming technologies these sources of information will still be developing alongside the development of the technology itself (Al-Senaidi et al., 2009; BenMessaoud et al., 2011; Damschroder et al., 2009; Tester & Langridge, 2010). This points to an important difference between the availability of information sources for established and upcoming technologies.

I posit that expectations can play a role in the process of user belief formation in the implementation processes of upcoming technologies in emerging technological fields. Many scholars have shown that expectations are important to the development of emerging technologies, playing a role in creating legitimacy and protected niches (Borup, Brown, Konrad, & Van Lente, 2006; Hekkert, Suurs, Negro, Kuhlmann, & Smits, 2007; Ruef & Markard, 2010; Schot & Geels, 2008; Van Lente, 1993), and steering development efforts (Alkemade & Suurs, 2012; Hekkert et al., 2007; Konrad, 2006; Schot & Geels, 2008; Van Lente, 1993). While these studies have traditionally had a meso- or macro perspective to expectations, this research focus on their impact on a micro level, in how they are capable of reducing the uncertainty of individuals. The dictating role of expectations described above may reduce users' uncertainty on the technology at stake, its future markets, and it societal context (Bakker, Van Lente, & Meeus, 2011). In this sense, expectations substitute for information that would otherwise be available when implementing established technologies, possibly affecting the formation of user beliefs. The second ambition of this research is therefore to determine the role expectations play in the user's belief formation process.

Integrating both ambitions, the aim of this research is to study the role of expectations in affecting user acceptance in implementing upcoming technologies in emerging technological fields. It will do so by attempting to answer the following research question:

> *To what extent do users' technological expectations influence user acceptance in the implementation process of upcoming technologies in emerging technological fields?*

The research embraces a multiple case study approach in which 11 cases of upcoming technologies are studied in the Dutch tissue engineering field; a collective of cells, engineering and materials methods, and bio- or physicochemical factors aimed at improving or replacing biological functions. Tissue engineering (TE) is an especially relevant field to study because of its still highly emergent character, where developments on the materials used for the implants, the cells used for regeneration of tissue, and the manufacturing techniques are all still on-going (CIRM, 2012; Fisher & Mauck, 2013; Horch, 2012). This naturally means that in general uncertainty still exists on the development and use of TE constructs. At the same time, however, the clinical application of some tissue engineered constructs is starting to take off (Horch, 2012), which ensures the availability of relevant cases. Additionally, researchers and developers of TE constructs in particular have a relatively unified view of its future applications, namely developing in vitro physiological models to study disease pathogenesis and develop therapeutics ('organ-on-a-chip'), and engineering whole organs for human implantation (Lanza, Langer, & Vacanti, 2011;

Novosel, Kleinhans, & Kluger, 2011). This indicates the presence of expectations on what TE could and perhaps should be. The combination of the existence of upcoming technologies in an emerging technological field and the presence of uncertainty and technological expectations makes TE an appropriate field of study for this research. Cases include TE technologies that are in preclinical development as well as technologies that are currently studied in patients in Dutch hospitals. These are also expected to be the implementers and users of future versions of TE constructs, meaning that insights in their current practices might also help their implementation processes of future technologies.

This research contributes to the literature by testing TAM and TT, two previously widely used theoretical models, in a new empirical setting, namely the implementation of upcoming technologies in an emerging technology field. Additionally, this research adds on these models by exploring the role of expectations in the belief formation process of users. By applying this extended model on multiple cases in the tissue engineering field, it provides an empirical assessment to the scarce literature on technological expectations and their influence on user acceptance in technology implementation processes today. In doing so, this research improves the understanding of the implementation process of upcoming technologies, creating awareness of the possible importance of technological expectations among developers and users. They may use this knowledge to improve their implementation processes, possibly increasing the chances of a successful implementation process.

The thesis will continue with the theoretical framework of this research, describing the important aspects of TAM, TT, and the expectations literature, and further elaborating on the previously mentioned research ambitions. Following the above will be the methodology chapter, describing the research design, case selection process, and data collection, preparation, and analyses steps. Next, will be the results section, systematically recounting the obtained data. Consequently, the research will summarize the findings in the conclusions chapter. It ends with the discussion chapter, recapping the course of the research, its implications and limitations, and providing insights into possible future research objectives.

2 Theoretical framework

The following chapter describes the theoretical basis of the two research ambitions. Starting with the importance of user acceptance in the implementation of upcoming technologies, it provides an overview of the theories of TAM and TT, specifically illustrating the significance of user beliefs. Next, the foundation upon which these user beliefs are based will be discussed, including the potential role that technological expectations can play in supporting this foundation. It concludes with a conceptual model that integrates the different theoretical concepts and relations into one figure.

2.1 User acceptance in technology implementation processes

The implementation of new technologies has continuously been reported to be critical to the sustained competitiveness for many organizations (Day et al., 2004; Edmondson, Bohmer, & Pisano, 2001; Freeman & Soete, 1997; Porter, 1998; Utterback, 1996). However, similarly extensive is the evidence on the difficulty with which implementers achieve successful implementation of technologies (Bhattacherjee, 1998; Camarinha-Matos et al., 2004; Damschroder et al., 2009; Day et al., 2004; Henderson & Clark, 1990; Kimberly & Evanisko, 1981; Luo et al., 2010; Metzker, 2005; Tushman & Anderson, 1986). Based on Edmondson et al. (2001), this research defines successful implementation as the incorporation or routine use of a technology on an ongoing basis in an organization.

An important precondition to the routine use of a technology is user acceptance (BenMessaoud et al., 2011; Karsh, 2004). A multitude of studies has been conducted on determining the factors that explain user acceptance in technology implementation processes within organizations, which led to a handful of theoretical models. The most widely accepted and used model is the technology acceptance model (TAM), praised for its parsimony and its predictive and explanatory power (Lee, Kozar, & Larsen, 2003). A lesser known and slightly different orientated theory is the theory of trying (TT). This theory challenged TAM and other similar theories by stating they have certain boundary conditions related to the dependent variable of user acceptance. This research emphasizes both theories, as each has its distinct power, and will further elaborate on them in the following sections.

2.1.1 The technology acceptance model (TAM)

Introduced by Davis (1986), TAM is built on the theoretical linkages of the theory of reasoned action (TRA) as proposed by Fishbein & Ajzen (1975) and later refined by Ajzen & Fishbein (1980). TRA is a very general theory, “designed to explain virtually any human behavior” (Ajzen & Fishbein, 1980: p. 4). TRA specifies that individual behavior is preceded by the individual’s intention to perform the behavior (see Figure 1). Behavioral intention, in turn, is determined by the individual’s attitude towards the behavior and the

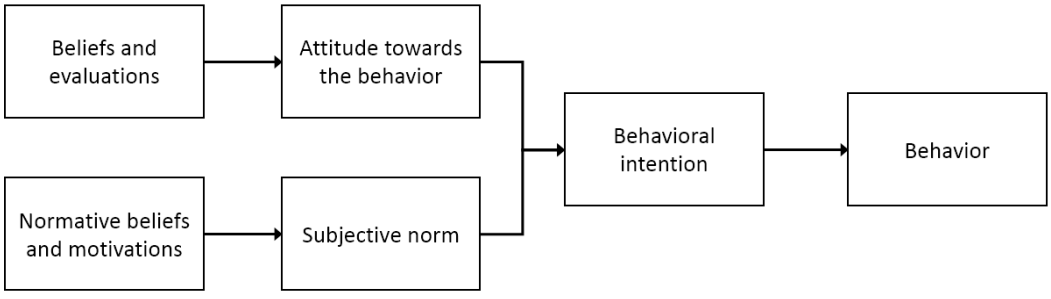

Figure 1 Overview of the concepts of the theory of reasoned action (TRA) as proposed by Ajzen & Fishbein (1980).

subjective norm. Attitude refers to an individual's general affective response toward the behavior, while subjective norm refers to the assessment of individuals to the extent that others would desire the (non)performance of the behavior (Agarwal, 2000). Attitude towards the behavior is determined by an open set of beliefs about the consequences of performing the behavior, weighted by the individual's evaluation of each consequence. Similarly, subjective norms are determined by an open set of beliefs about the extent to which others belief an individual should perform the behavior, weighted by the individual's inclination to comply to these beliefs.

While TRA has shown extensive empirical value in explaining and predicting individual behavior (Ajzen & Madden, 1986; Mathieson, 1991; Sheppard et al., 1988; Taylor & Todd, 1995), Davis (1986) explored a new model, TAM, that would not only be helpful for the prediction of behavior but also for the explanation of it, so that users of the model could identify *why* a certain technology may be unacceptable, and possibly make suitable readjustments. Because TAM is specifically aimed at explaining a specific behavior, i.e. user acceptance of technology, Davis (1986) was able to identify a small number of external factors that could impact internal beliefs, attitudes, and intentions. First of all, Davis (1986) proposed that only two beliefs – perceived ease-of-use and perceived usefulness – predict an individual's attitude towards the use of a technology (see Figure 2). Perceived ease-of-use (PEOU) relates to the degree to which the user expects the use of the technology to be free of effort, while perceived usefulness (PU) relates to the user's assessment that using a technology will increase their job performance. PU is also expected to exhibit a direct effect on behavioral intention in addition to its indirect effect on intentions via attitude, because "within organizational settings, people form intentions toward behaviors they believe will increase their job performance, over and above whatever positive or negative feelings may be evoked toward the behavior per se. This is because enhanced performance is instrumental to achieving various rewards that are extrinsic to the content of the work itself, such as pay increases and promotions" (Davis et al., 1989: p. 986).

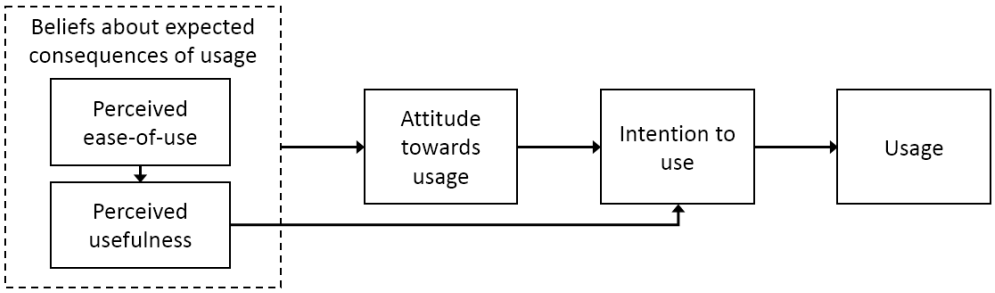

Figure 2 The technology acceptance model (Davis et al., 1989).

Additionally, Davis (1986) and Davis et al. (1989) made a first effort at describing the antecedents and determinants of these user beliefs. Better understanding of these external factors were necessary to allow for the design of effective interventions. They proposed that PEOU is based on a combination of objective design characteristics that determine the usability of the technology, and personal competence and supporting factors of training, documentation, and user support consultants (Davis et al., 1989). Similarly, Igbaria et al. (1995) proposed that individual (user training, user experience), organizational (end-user and management support), and system characteristics (system quality) determine PEOU. Venkatesh & Davis (1996) compiled these factors in two components: objective usability and self-efficacy (see Figure 3).

Davis et al. (1989) propose that PEOU itself is also a determinant for PU, to the extent that increased ease-of-use contributes to improved performance, e.g., by redeploying saved effort, enabling a person to accomplish more work for the same effort. In addition to the indirect effects objective design characteristics can have through PEOU, they also directly affect PU (Davis et al., 1989). When two technologies are equal in PEOU but one outperforms the other – based on their objective design characteristics – that particular technology will be perceived to be more useful. Venkatesh & Bala (2008) identify this effect under the job relevance determinant. They add that social influence, i.e. the degree to which users believe technology usage is socially desired and will enhance their social status, is also an important determinant to PU (see Figure 3).

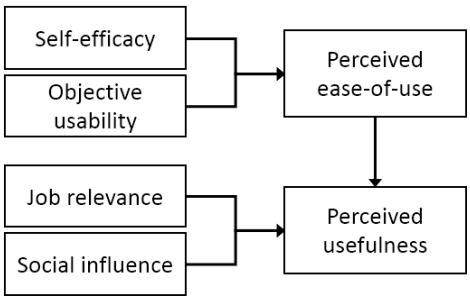

Figure 3 Determinants of PEOU and PU (Davis et al., 1989; Igbaria et al., 1995; Venkatesh & Bala, 2008; Venkatesh & Davis, 1996).

Finally, Davis et al. (1989) proposed that the subjective norm included in TRA be excluded for TAM because of its difficulty in distinguishing the direct effects of norms on intentions from indirect effects via attitude. What remains are clearly defined beliefs in a parsimonious and practical model which has been widely accepted and used for user acceptance studies in many different technological fields (King & He, 2006; Lee et al., 2003).

2.1.2 The theory of trying (TT)

Even though TAM has repeatedly exhibited explanatory and predictive power towards usage behavior, several studies have argued for a broadening of its dependent variable (Agarwal, 2000; Bagozzi, 2007; Barki, Titah, & Boffo, 2007; Benbasat & Barki, 2007). In their TT, Bagozzi et al. (1992) argue that models incorporating attitudes towards actions, such as TAM, are limited in the sense that they assume that when an individual forms the intention to act out a behavior, it will not encounter any impediments on its way. In other words, they expect that when a favorable attitude causes a behavioral intention, the behavior itself will be largely *unproblematic* to carry out. However, Bagozzi et al. (1992) argue that some actions towards the acceptance of a technology can be *problematic*. Learning to use a new technology, for example, can be considered as such an action, as it may be hindered by factors such as skill limitations, environmental deterrents, or time constraints. TT posits that learning to use technologies is a form of trying, which is preceded by the intention to use, which in turn is preceded by the intention to try (see Figure 4). Bagozzi et al. (1992: p. 662) state that "when the possibility of trying but failing to perform a given action becomes salient to an individual, the consequences of failing may influence their intentions to attempt the action". Therefore, unlike TAM, the intention to try is not based on the unidimensional attitude towards a behavior, but it is conceptualized by a more complex, multi-dimensional structure towards goal pursuit. Intentions to pursue a goal are "driven by attitudinal reactions toward the gains foreseen by achieving the goal, the losses anticipated should one fail, and the pleasurable and noxious experiences on will accrue along the way" (Bagozzi et al., 1992: p. 679) (see Figure 4). The beliefs that determine these attitudinal reactions are, however, not as clear and parsimonious as the beliefs in TAM. In general, they are about expected impediments towards the process of goal pursuit consist, but they can consist of a variety of internal factors such as skills, abilities, knowledge, and adequate planning, and external factors such as time, opportunity, and dependence on the behavior of other people (Ajzen &

Madden, 1986; Bagozzi et al., 1992). The greater complexity of TT contributes to the fact that it is not so widely employed and accepted as TAM.

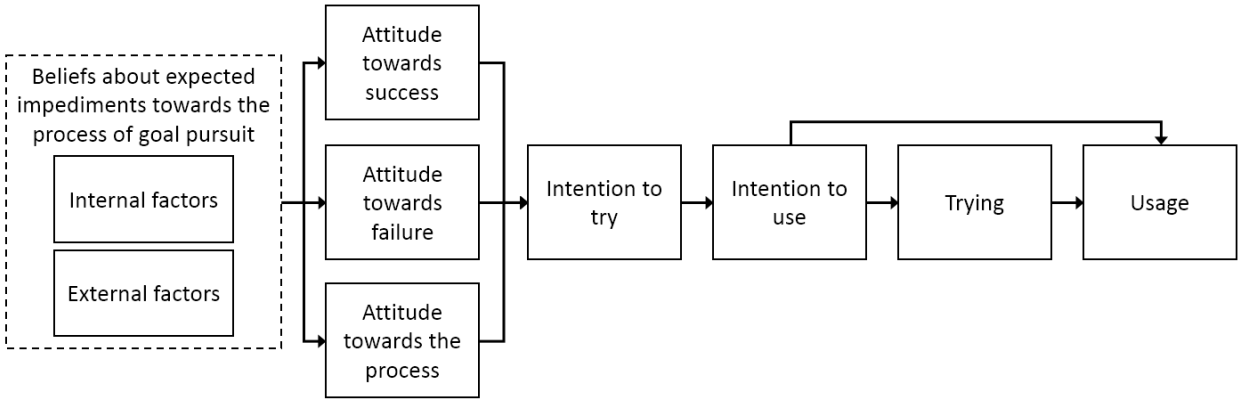

Figure 4 The theory of trying (Bagozzi et al., 1992).

2.1.3 TAM and TT for upcoming technologies in emerging technological fields

While TAM and TT have initially been developed for user behavior in the implementation process of information technologies, and their validation has been achieved through studies with other established technologies, their underlying ideas can be valid for upcoming technologies in emerging technological fields as well.

First of all, the fundamental sequence of factors that underlie TAM and TT, i.e. external variables → beliefs → attitudes → intentions → behavior, has been derived from theories embedded in a much wider social environment and can be universally applied to predict any type of human social behavior (Ajzen & Fishbein, 1980; Ajzen & Madden, 1986). Indeed, while this underlying mechanism has been successfully used to predict user acceptance in the implementation process of information technologies (Davis et al., 1989; Mathieson, 1991; Taylor & Todd, 1995), it has also demonstrated predictive capabilities for example in students' attendance (Ajzen & Madden, 1986), consumer behavior (Sheppard et al., 1988), usage of birth control (Davidson & Morrison, 1983), and voting behavior (Jaccard, Knox, & Brinberg, 1979). Based on this universal claim of predictive power of the underlying mechanism, it is reasonably assumed that this framework also applies to individual usage behavior in the implementation of upcoming technologies in emerging technological fields. The first ambition of this research is therefore not to establish anew every individual concept and relationship that TAM and TT propose, but rather to determine the relevance of the concepts that are specific to usage behavior, i.e. the beliefs about expected consequences of usage and impediments towards the process of usage, in the implementation process of upcoming technologies in emerging technological fields.

Based on current research, it is expected that these technology usage-specific beliefs are relevant to the implementation of upcoming tissue engineering technologies as well. TAM supposes that for users to accept a technology, they need to believe it will be useful to them and easy-to-use. These prerequisites of the technology have shown to be relevant to the implementation of other upcoming healthcare technologies in hospitals as well. In their study of the implementation of robotic-assisted surgery, BenMessaoud et al. (2011) demonstrated that PU and PEOU were important factors in surgeons' acceptance and use of the technology. This is underlined by Edmondson et al. (2001) who, in their study of the implementation of a new technology for cardiac surgery in 16 different hospitals, described that

even though the technology users complained bitterly about the many hours of hard work with a very complex and difficult procedure, they were enthusiastic to be picked to participate in the trials. These users were motivated by the growing confidence in the technology and the belief that patients benefited enormously from the new procedure. It also shows for more supporting technologies such as the electronic health record (ECR), as Greenhalgh et al. (2008) show in their case analysis of ECR in the UK. They report that adoption of the technology is and will be slow due to the high complexity of the system making it difficult to use, and the divided view towards its relative advantage, i.e. the PEOU and PU of the system.

While these technologies are not necessarily similar to upcoming tissue engineering technologies in their technological characteristics, the implementation environment, i.e. the implementing organization (hospitals and other healthcare institutions) and the specific users (e.g., physicians, surgeons, and other medical practitioners), are comparable. Therefore, this research hypothesizes that for Dutch hospitals and other healthcare institutions it follows that:

> *HIa. If they implement upcoming tissue engineering technologies, then belief concepts of TAM—perceived usefulness, and perceived ease-of-use—are antecedents to user acceptance of the technology.*

Similarly, the idea of TT that users may face internal and external impediments in their goal pursuit of using a technology has been shown to be prevalent in the implementation of other upcoming technologies in hospitals as well. In their literature review of innovation diffusion in health service organizations, Greenhalgh et al. (2008) described several case studies in which they underlined the possible constraining effects of internal and external factors. For example, the success of telemedicine initiatives in the UK was hampered by the lack of supportive organizational environments in the implementers' organizations as well as inadequate linkages between the developer and the implementer, in addition to the high costs and low ease-of-use of the systems.

Additionally, in the same study as previously mentioned, Edmondson et al. (2001) described how the new technology for cardiac surgery disrupted existing work routines of operating room teams. What they too recognized, was that the organizational routines often reinforce the status quo (Levitt & March, 1988; Nelson & Winter, 1982; Orlikowski, 2000). The operating room teams in their study that were not able to break away from the existing routines ended up with limited use of the new technology, whereas operating room teams that did succeed in developing new routines were much more successful in their implementation. This development of new routines materialized through a learning process in which mutual adaptations of individuals and technology took place in order to fit the technology to the operating room team. This learning process to overcome initial impediments was thus shown to directly affect the eventual use of the technology.

Based on the above, this research hypothesizes that for Dutch hospitals and other healthcare institutions it follows that:

> *HIb. If they implement upcoming tissue engineering technologies, then belief concepts of TT—perceived internal and external impediments—are antecedents to user acceptance of the technology.*

2.2 The basis of user beliefs

While the user beliefs for both TAM and TT are expected to be similar for implementation processes involving upcoming technologies and implementation processes involving established technologies, this may not necessarily be the case for how the determinants of these beliefs are constructed.

As slightly touched upon previously, research proposes that the determinants for user beliefs are influenced by a variety of external factors. Davis et al. (1989) mention the importance of objective design characteristics, training, documentation, and user support consultants. Igbaria et al. (1995) underline these factors and add the importance of user experience and management support. Venkatesh & Bala (2008) underline all of these factors as well, but specify support further towards management support, organizational support, and peer support. They also add user participation and incentive alignment as important external factors.

An important characteristic of most of these factors is that they are technology-specific. This is very obvious for some factors, such as the design characteristics and documentation, but it is also true for training and various other types of support. When implementing established technologies, these aspects are likely to be well-defined: technological design characteristics are concrete, training programs with corresponding manuals will be set up, and there generally will be knowledge on how to use the technology and its expected outcomes (Damschroder et al., 2009). Therefore users have a basis of information on which they can form their beliefs.

When implementing upcoming technologies in emerging technological fields, however, such a solid base of information is not necessarily present. Several studies on the implementation of information technologies in education have emphasized the difficulty in securing positive users' beliefs and attitudes when ambiguity towards the technology exists. Hew & Brush (2007) described how teachers that were unconvinced of the value of the implemented technology due to a lack of supporting evidence were hesitant to integrate it into their daily practice. Additionally, Al-Senaidi et al. (2009) described the importance of technical training in order for teachers to feel confident in using the technology. O'Neill et al. (2004) add that it is significant to the success of the implementation process if users have access to forms of technical support. Rogers (2000) underlines this by stating that major barriers to user acceptance of information technology in schools are the lack of institutional and technical support. These studies seem to display one of the intrinsic characteristics of upcoming technologies; that because they are not yet widely used and accepted, there is not much evidence on which users can base their beliefs.

This is also underlined in other studies of healthcare technology implementation. Freedman et al. (2005) reported that technologies in long-term care settings translated poorly to practice because of the lack of systematic, readily accessible, and accurate information, specifically on what the technology was supposed to do and how it worked. In a different study on the implementation of a new robotic-assisted surgery, BenMessaoud et al. (2011) state that surgeons preferred traditional practices, as the evidence of the new surgery translating to improved patient outcomes was lacking. They add that surgeons' lack of acceptance is also due to the inadequacy of training standards. Both studies clearly point to the lack of a solid evidence base due to the fact that the particular upcoming technology is not yet widely used and accepted, meaning there are few comparable cases from which users can extract insights on how to use the technology and what its potential consequences are. This is underlined by the study of Greenhalgh et al. (2008) on the implementation of an organizational innovation in clinical commissioning; a slightly different case but one that is still relevant due to its particular context of hospitals being the implementers

and medical practitioners being the users. The belief of the usefulness of this new nationwide program contrasted between different individuals as there was no clear evidence of the consequences of its introduction. Finally, especially in cases of tissue engineering technologies where users are engaged in testing the product (e.g. clinical trials), the design characteristics of the technology may still be under development.

The apparent absence of solid information sources necessitates alternative sources on which users of upcoming tissue engineering technologies can build their beliefs.

2.2.1 The role of promises and expectations

In recent years, a growing number of social science studies have underlined the significance of promises and expectations in science and technology innovation. Expectations on technological developments can be described as "real-time representations of future technological situations and capabilities" (Borup et al., 2006: p. 286). Technological promises largely overlap with expectations but emphasize to a higher degree a normative character: "expectations [as] wishful enactments of a desired future" (ibid). According to Van Lente & Rip (1998), the social function of promises and expectations in technological development follows a cycle (see Figure 5). The technological promises arise from signaling an opportunity based on the combination of techno-scientific possibilities and societal gains. Technologists will generally share these promises with other actors because the broad acceptance of these promises can create (local, field, or macro) agendas; providing interest and creating legitimacy for the technology (Borup et al., 2006; Hekkert et al., 2007; Ruef & Markard, 2010; Van Lente, 1993). The subsequent work that is done is evaluated based on the promises made: the technology must fulfill the functions that were initially promised. As such, promises turn into prerequisites of action (Budde, Alkemade, & Weber, 2012; Konrad, 2006; Van Lente & Rip, 1998; Van Lente, 1993). As actors base their activities on these requirements, the technology search is steered towards the prevailingly accepted promises (Bergek, Jacobsson, Carlsson, Lindmark, & Rickne, 2008; Hekkert et al., 2007; Van Lente & Rip, 1998). The results of these activities may start new mini-cycles of increasingly detailed opportunities with their promises, requirements, and activities; starting the cycle anew (Van Lente & Rip, 1998).

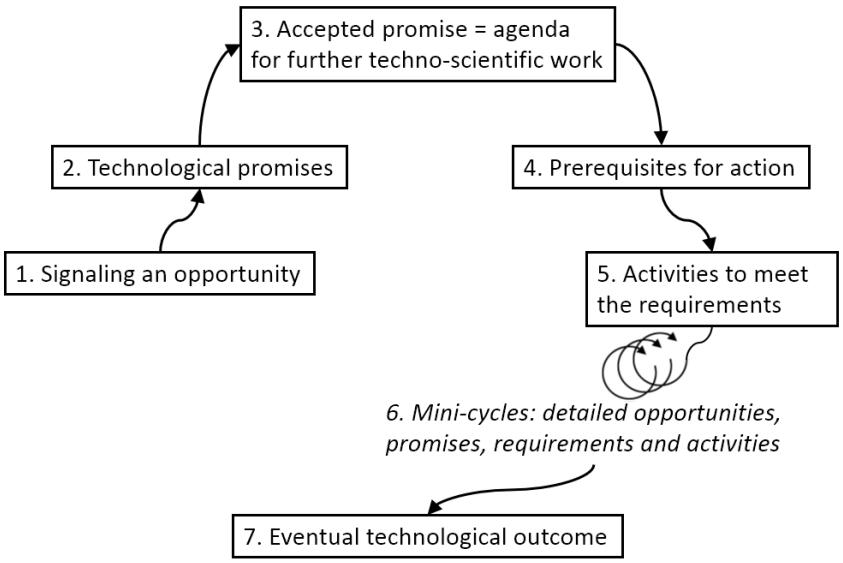

Figure 5 The social function of promises in technological developments (Geels & Smit, 2000; Van Lente & Rip, 1998).

What we take away from this is that actors are guided in their activities by promises turned expectations. Their individual expectations are based on the exchange of expectations in interactions with many others (Konrad, 2006): they are continuously adjusted to the specific expectations of other actors and to the broadly shared, collective expectations.[1] Even when the feasibility of functions of the technology has not been established – i.e. when the technology is not yet developed – actors base their strategies on this vision of the future. Konrad (2006) described that "an expectation here becomes a quasi-certain prerequisite of action where *alternatives need no longer be considered* [italics added]". In other words, actors' uncertainty of technology development paths are reduced: technology use and the benefits of use become salient. Based on this dictating role, an individual's expectations on the technology at stake, its future markets, and it societal context (Bakker et al., 2011) can thus take away some of the perceived uncertainty in the development process of upcoming technologies in emerging technological fields. In this sense, expectations substitute for information that would otherwise be available when implementing established technologies (see Figure 6). For the second hypothesis this research therefore states that for users involved in the implementation process of upcoming tissue engineering technologies in Dutch hospitals it follows that:

> *HII. If users subscribe to expectations on the implemented technology, then the expectations act as an information substitute in the formation of their beliefs on the technology.*

While the sociology of expectations has traditionally had a meso- or macro perspective, this research will focus on how expectations on an individual level are capable of influencing individual user behavior in the implementation process of upcoming tissue engineering technologies. Special attention will be paid to how these expectations have come into existence, i.e. to what expectation sources individuals relate.

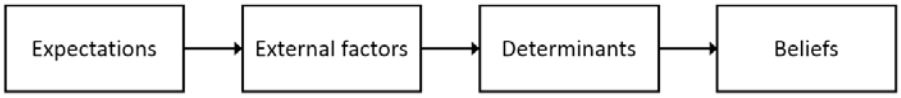

Figure 6 The possible effect of technological expectations on the external factors that influence determinants of user beliefs.

2.3 From expectations to user behavior

This research studies the convergence of the abovementioned theoretical insights by establishing to which extent expectations on the emerging technology can influence user behavior in the implementation process. It is expected that technological expectations can take away some of the perceived uncertainty of users and in doing so create an alternate information base on which users may build their beliefs of the technology. As such, technological expectations may substitute for concrete knowledge on technology use and consequences of use which are commonly available when implementing established technologies. While these notions mostly relate to the current version of the technology that is implemented, the sociology of expectations literature in particular emphasizes the performative power of expectations on future states of the technology. This research will therefore not necessarily focus on expectations of the current version of the implemented technology, but instead remain open to any and all technological expectations that might have had an impact on the formation of beliefs towards the use

[1] Specific expectations are those that can be said to be held by and attributable to individual actors or groups of actors, while collective expectations are not attributable to specific actors or groups of actors, but may be considered to be the expectations of generalized others (Konrad, 2006).

of the current version of the technology. These impacts on the formation of beliefs will – according to TAM and TT – ultimately have an influence on user behavior.

The described theoretical relationships are displayed in the conceptual model presented in Figure 7, with emphasis on the proposed hypotheses.

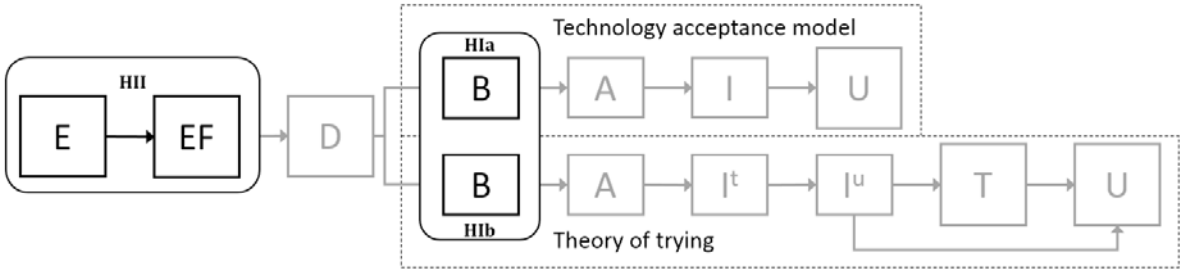

Figure 7 Conceptual model. E: user's technological expectations; EF: external factors; D: determinants of user beliefs; B: user beliefs; A: user attitudes; I: user intentions; T: trying to use; U: technology use; ^{t} and ^{u} refer to trying to use and technology use respectively. HIa, HIb, and HII signify the proposed hypotheses.

3 Methodology

3.1 Research design

This research had two distinct ambitions: (i) to test the concepts of user beliefs of TAM and TT, and (ii) to explore the role users' technological expectations can play in the formation of users' beliefs – both in the implementation process of upcoming tissue engineering technologies in Dutch hospitals and other health institutions. While testing (part of) a theory generally solicits a quantitative research approach, the aim to explore a new theoretical relationship between expectations and external factors of the belief formation process specifically requires a qualitative research method. Even though the choice for a qualitative approach limits the robustness of testing the concepts of user beliefs of TAM and TT compared to a quantitative research design, I prefer it for the value it has to the exploration of the second research ambition. This research therefore employed a case study approach, as case studies are a way of gaining in-depth, qualitative understanding of the phenomenon in its natural setting (Eisenhardt, 1989). In particular, this research embraced a multiple case study approach as it is generally regarded as more robust, because it allows for the critical assessment of data through triangulation, contributing to the credibility and validity of the research (Eisenhardt, 1989; Yin, 2003). The pairing of ambitions did also cause a duality in the rest of the research design, specifically in the data preparation and analysis steps. Where needed, the following sections of the methodology will make explicit to what research ambition the specific paragraphs apply. The unit of analysis for both research ambitions is the technology user involved in the implementation of upcoming tissue engineering technologies.

3.2 Case selection

Cases have been selected based on the technology implemented—it had to be a TE technology that either is a final product, an intermediate product that is being user-tested, or a technology which is still under development but has a clear future application—through the use of desktop research. Before the search started, I was aware of the fact that there are not many tissue engineering technologies already being implemented, especially if geographically limited to the Netherlands. Therefore, the initial search for cases was orientated broadly, starting with the utilization of Google, basically in order to find anything related to tissue engineering in the Netherlands, combined with the database of LexisNexis, in order to specifically scan reliable, Dutch news sources, the scientific databases of Google Scholar and Scopus, to find published articles on Dutch tissue engineering, and the clinical trial database of EU Clinical Trials Register, specifically searching for cases in which tissue engineering is applied. Keywords that were used for this first exploration were blanket terms such as 'tissue engineering' and 'regenerative medicine', combined with keywords aimed at capturing the implementation part such as 'implementation', 'product', and 'use' and more user-focused keywords such as 'user', 'physician', 'doctor', and 'surgeon', and geographical filter words such as 'the Netherlands', 'NL', and 'Dutch'. This broad inquiry produced less results than expected, not necessarily because of the overall moderately limited activity in the tissue engineering field, but rather due to the variety in terminology, with actors often choosing to not use the abovementioned general terms at all, but rather describe their work with terminology related more to their specific technologies. The broad Google search did, however, lead to websites of umbrella organizations in the Netherlands, e.g., the Dutch Association for Biomaterials and Tissue Engineering (NBTE), the Dutch Program for Tissue Engineering (DPTE), and the Dutch Institute of Regenerative Medicine (NIRM). These sources listed members of their groups and provided information on research areas, allowing the snowball sampling of not only concrete cases, but also new, more specific search terms that were related to the various application areas of tissue engineering. These new search terms included 'bone', 'cartilage', 'blood

vessels', 'urethra', 'urogenital', 'skin', 'heart valves & vessels', 'organ-on-a-chip', and 'cell culture'. A new search using these keywords in combination with the previously mentioned keywords led to additional results in all databases. The searches in Google Scholar and Scopus resulted in some useful publications in which the authors were affiliated with research institutions or companies that were active in the tissue engineering field, again allowing for the snowball sampling of cases. The umbrella organizations also emphasized the involvement of universities in the tissue engineering field. For this reason, I combined the above keywords specifically with the locations of Dutch universities, e.g., Delft, Eindhoven, Rotterdam, which led to some additional cases of research and development of tissue engineering technologies. The above inquiries eventually resulted in a list of 45 cases of which I approached at least one contact person. In total I sent out 53 individual requests for participation in the research, excluding follow-up inquiries. Actually getting into contact and convincing respondents to contribute to the research was, however, more difficult than anticipated. Especially users, both user companies as well as clinicians, turned out to be non-responsive to the requests. Eventually 14 actors involved with 11 different technologies in the tissue engineering field were willing to participate in the research.

Even though the sampling of cases has been done in an attempt to establish a good correspondence between hypotheses and the selected cases, otherwise known as purposive sampling (Bryman, 2008), the individual respondents consist mainly of researchers who have active relationships with the end users of their technologies. These researchers were able to provide relevant insights because of their extensive understanding of the users' needs and practices due to many of them closely working together with users. Their knowledge has also contributed to the context information about tissue engineering research which users may not have been able to provide. However, while I believe the acquired insights to be comprehensive, it should be noted that ideally I would have preferred to verify the insights with users. Implications of this condition are considered further in the discussion chapter. An in-depth description of the cases is presented in appendix A.

3.3 Data collection

An accepted way of obtaining data on individual cases is through the use of interviews. Because the research covers a variety of complex tissue engineering technologies, interviewees were first asked some basic questions regarding the application and value of the technology, providing the technological and contextual information needed to adequately interpret the remainder of the interview.

Following this introduction, interviewees were questioned about the theoretical concepts of this research. The duality in research ambitions, however, demanded the use of different types of interview questions. The first ambition, testing the concepts of user beliefs, required specific interview questions relating to the theoretical concepts of TAM and TT. To this end, questions were used that have formerly been validated in earlier research (Bay & Daniel, 2003; Kim, Chun, & Song, 2009; Lederer, Maupin, Sena, & Zhuang, 2000; Zint, 2002). For the exploration of the role of expectations in the formation of user beliefs, the interview questions were deliberately kept more open, inquiring interviewees more generally about their views on the role of expectations. This gave the interviewees the ability to share answers that could deviate from or further broaden the understanding of the proposed theoretical concepts. To accommodate both types of interview questions, the research employed semi-structured interviews, following predetermined topics and questions but also allowing for deviation and follow-up questions (Bryman, 2008). An overview of the interview questions can be found in appendix B.

In order to preserve all the information that was presented by the interviewees, all interviews were recorded and transcribed.

3.4 Data preparation

The use of semi-structured interviews unmistakably led to a certain degree of irrelevant deviation. Even though this was attempted to be kept to a minimum through assertive questioning, not all data from the interview transcripts was useful to this study. Additionally, not everything that was useful to this study was neatly organized and ready for analysis. Therefore, there first had to be a preparation step. This data preparation was done through a coding process, entailing the "reviewing [of] transcripts [...] and giving labels (names) to component parts that seem to be of theoretical significance" (Bryman, 2008: p. 542). Again, the duality of the research ambitions necessitated different coding strategies.

For the data that was intended for testing user beliefs, the coding process followed a coding scheme based on the theoretical concepts that were introduced in the theory section. The important concepts here were perceived ease-of-use and usefulness, and impediments towards the process of technology usage. Raw interview data was coded with these sensitizing concepts in mind. This process is otherwise known as selective coding (Strauss & Corbin, 1990).

For the exploration of the role of expectations, the first step in this process was to break down the raw data to examine and compare it, eventually yielding concepts that would be grouped together to form categories. This is process is otherwise known as open coding (Strauss & Corbin, 1990). The open coding of the data resulted in a preliminary coding scheme which was used to evaluate the data further. The second step was to bring coherence to the codes through a process of axial coding. This entailed "reassembling the data by searching for connections between the categories that have emerged out of the [open] coding" (Bryman, 2008: p. 543). Important in this step also was the assessment of contradictory arguments presented by the interviewees. The interviews were evaluated in this way until theoretical saturation was achieved. The final step then was to review the coded interviews and code the remainder of the interviews with the final coding scheme representing the core categories, similar to the selective coding done for the first research ambition. For both research ambitions the process was kept open to allow for the emergence of new concepts. This ensured that no interesting (contextual) data was lost.

3.5 Data analysis

The first step in analyzing the data was to determine whether or not the concepts of user beliefs of TAM and TT are present in the implementation processes of the selected cases. Specifically, the user beliefs about expected consequences of technology usage – perceived ease-of-use and perceived usefulness – and the presence of beliefs about expected impediments towards the process of technology usage – consisting of several internal and external factors, and technology usage. This was done by composing the overall users' perspective from the multiple user interviews through triangulation of the answers, keeping statements only if they were reported by the majority of the users. In a similar manner it was determined whether these user beliefs related to the eventual technology usage of the user. This analysis allowed for the testing of hypotheses Ia and Ib. These hypotheses are accepted when the overall users' perspective reflects the presence of the concepts of user beliefs of TAM and TT in the implementation of tissue engineering technologies and their antecedence to eventual technology usage.

The second step consisted of determining the basis of information on which users base their beliefs, and whether or not expectations play an information substituting role when implementing tissue engineering

technologies. Because this ambition is explorative in nature, no data was in itself disregarded, but rather common statements were more emphasized. This highlighting of the most relevant insights while maintaining interesting side remarks provided the most comprehensive view of the proposed theoretical relationship. However, actually testing hypothesis II was done similarly to step 1; by composing an overall view, this time on the information channels, subjects, and types, through triangulation of the answers, keeping statements only if they were reported by the majority of the interviewees. Hypothesis II is accepted when expectations have been determined to be present in users' decisions to use a technology. The testing of the hypotheses provides the basis for the final answer on the research question.

4 Results

The following sections will discuss the results as derived from the conducted interviews. From the interview data it became clear that the users of upcoming tissue engineering technologies are not necessarily only clinicians and that beliefs are not necessarily constricted to the ones introduced in the literature. The following sections will discuss these findings as structured as possible, following the two ambitions described earlier in the research. The first three sections report on findings concerning the presence of user beliefs in the tissue engineering technology implementation process and their relation to user acceptance. The final section relates to findings concerning users' information base and the potential role of expectations.

4.1 Clinicians' beliefs

While the interviews were specifically directed towards user beliefs and their relation towards user acceptance as proposed by the established theories of TAM and TT, there were also some interviewees that reported on the relation of user beliefs and their involvement in technology development. While not directly related to user acceptance, these findings are auxiliary to the overall technology development and implementation process and can therefore be of interest to researchers and practitioners alike. The findings are described separately in their own paragraph.

4.1.1 Beliefs about expected consequences of technology usage (TAM)

The following paragraphs describe the factors that were reported by the interviewees as motivations why clinicians are likely to want to use upcoming tissue engineering technologies.

4.1.1.1 Perceived usefulness

Unequivocally one of the most apparent motivations for clinicians to be interested and/or invested in a research line and an important demand for the final product is that the application of the technology should help improve the wellbeing of patients [I1, I4, I5, I6, I9, I10, I12, I13]. Whether the end product is a replacement for currently insufficient therapies or a way of treating previously untreatable diseases, the end goal is always to cure the patient. An illustrative example is presented by interviewee 12:

> *"I have had discussions about this in the early years. Why would you treat a patient with those first generation stem cells that do not work optimally? The clinicians responded that they know it is a safe procedure – that has been proven – so even if it only helps a little bit, it is worth it. It is better than doing nothing."*

This shows that even when a therapy may not work perfectly, is possibly expensive, and in general really just in an experimental phase, if it is safe and it benefits the patient even slightly clinicians will hold onto that usefulness despite any of the drawbacks. Interviewee 12 underlines this by stating that while clinicians will prefer an easy-to-use therapy, they will definitely switch to a more complex and difficult-to-use therapy if it is proven to be a qualitatively better alternative.

Interviewee 13 provides another interesting example in which clinicians demonstrate their urgency for useful therapies. When clinicians at their institution heard of the research that was being conducted by their colleague researchers, they asked them whether they could use that research for a new therapy that could help them treat chronic wounds that were currently not treatable. This led to a close collaboration between the clinicians and the researchers in which the possibilities of application of the research were

discussed and pursued. The clinicians were ultimately able to instigate or steer the research towards a for them potentially more useful therapy.

What is most telling, however, is that only one respondent found the need to bring up an example when asked the question why clinicians are interested in tissue engineering therapies; all others acknowledged that it is because they want to help patients and left it at that. Not because it is insignificant, but because it is self-explanatory; it goes without saying. As interviewee 5 states:

> *"Clinicians are committed to their patients. That is their profession."*

4.1.1.2 Perceived ease-of-use

Another important requirement set by clinicians is that therapies should be easy to use [I1, I2, I8, I12, I13], as illustrated by interviewee 8:

> *"I work together with clinicians who are very open to trying out new things. However, they do want to see an example of how it works. More importantly, it should be easy to use. If it gets too complicated, they often lose their interest."*

Interviewee 2 underlines this by stating that clinicians want to be able to work with a product that has proven itself and do so without hassle. Interviewee 8 adds that it needs to be foolproof, however, interviewee 9 actually states that the clinicians have a strong ability to alter and adapt where needed to implement the therapy in question. She adds that therefore clinicians are not expected to have any difficulties with implementing their particular therapy.

Additionally, the therapy should be easy to implement in the current treatment plans. For example, interviewee 13 mentioned that things such as lead times, dimensions, transport, and other logistics of their skin tissue constructs were discussed with the clinicians so that the developed therapy could painlessly be integrated into their current outpatient treatments.

A very practical issue that illustrates both the concepts of perceived usefulness and perceived easy-of-use is the type of bandage that is applied in the case of skin tissue constructs. Interviewee 1 explained that because different types of bandages can interfere with the skin tissue construct, it is important which type of bandage is used in the hospital in which the therapy is implemented. If the hospital happens to use a bandage that kills the skin tissue construct within days of application, clinicians will find that the therapy is not useful to them at all. At the same time, it is improbable that the hospital will change or broaden the types of bandages they purchase for this one therapy. If a clinician still wants to use it, and get good results, he or she will have to find a way to obtain a different type of bandage or work around this problem altogether, complicating the use of the skin tissue construct. Either way, the therapy will either be deemed not useful or too difficult to use, which is why interviewee 1 stated that in these cases the clinicians are not going to use the therapy. It also shows that environmental factors can play a significant role in the perception of individuals, something which will be further reflected upon later.

4.1.2 Beliefs about expected consequences of involvement in technology development

While the previous two beliefs have been the only ones that directly relate to technology usage, two interviewees also elaborated on the potential individual gains of being involved in the development of the technology.

4.1.2.1 Perceived reputation gain

It could be good for clinicians that also do a lot of research to attach their name to a promising, new technology. Interviewee 10 mentions this heightens their reputation and may open up further research possibilities. As will become apparent further on in the research, funding opportunities have been declining steadily for years with competition between different research groups increasing. An extra bit of exposure due to associations with the research frontier can thus be quite valuable for a researching clinician.

4.1.2.2 Perceived financial gain

Financial gain is another albeit debated factor that can motivate clinicians to be involved in the technology development process. Interviewee 5 reflects on the potential financial gain that clinicians may receive when they offer their services for the development of new technologies. For example, in the development process of their meniscus implant they plan to involve several orthopedists with whom they will have regular meetings in which the orthopedists are encouraged to think along with the research group and provide them with important design criteria. This is valuable to the research group as it allows them to create a product that will have support in its user base, because these users will recognize their ideas in the final design. While this touches upon the wish for usefulness of the final product as well, interviewee 5 mentions that the orthopedists will also likely request financial compensation for their time and effort. He believes that this might play a role in a clinician's decision to participate in these development efforts.

Interesting to note, however, is that interviewee 13 specifically stated that clinicians do not use and are not involved in technology development for their own personal gain, but that it is solely about helping their patients get better. With these two interviewees being the only ones explicitly discussing this topic, it is difficult to assess what is true. Being that no other interviewees reported this aspect as important, the truth leans slightly more towards perceived financial gain not being a factor.

4.1.3 Beliefs about expected impediments towards the process of technology usage (TT)

The following paragraphs describe the interviewees' perspectives on the potential impediments towards the process of upcoming tissue engineering technology usage as expected or experienced by clinicians.

4.1.3.1 Internal factors

While Ajzen & Madden (1986) proposed that internal factors such as skills, abilities, knowledge, and adequate planning could pose as impediments to the process of technology usage, none of these factors actually directly surfaced in the interviews. One might consider the need for easy-to-use therapies as an indication for the inability of clinicians to work with complex technologies, however, none of the respondents stated that this was necessarily a bottleneck; it was rather a preference. Interviewee 9 mentioned that no matter what you provide the clinician with, they will find a way to make it work. However, this does seem to argue for the importance of a clinician's skills and abilities, i.e. they need to know how to adapt to new therapies, but they are currently not a limiting factor because the clinicians are skilled individuals.

4.1.3.2 External factors

In contrast to internal factors, there are some external factors that could impede the process of technology usage.

Time

Clinicians are very limited in their ability to experiment and participate in development efforts for new technologies because they lack the time to do so. Interviewee 13 mentions that participating in the development of their skin tissue construct has proven to be a very labor-intensive process for the clinicians. This is not only the result of the actual clinical work they have to do, but also very much due to the intense load of paperwork that needs to be filled out. While filling out paperwork for most clinicians is not a very gratifying task in itself, what is more important is that they have to do this in their own time. Additionally, interviewee 2 mentions that perhaps only ten percent of a clinician's time is spent on research, which includes all research activities, because the vast majority of their time is consumed by regular patient care.

Opportunity

Furthermore, clinicians do not always get the right opportunities to use the technology. Interviewee 10 mentions that is important to the implementation of new therapies whether or not insurance companies cover the costs of its usage. As with any business entity, hospitals need to make decisions on where and how to spend their budget. So even if a therapy is essentially available for use in a hospital, if it is not covered by insurance, it will limit the opportunity of clinicians to actually use it in the clinic. Coverage by insurance is, however, tough to achieve because of the difficulty in demonstrating the efficiency of tissue engineering therapies. An example is described by interviewee 10, whose research team is trying to figure out how to conduct a fitting efficiency study for their one-step cartilage repair therapy:

> *"What is often needed, is a trial in which several therapies are compared; preferably a blinded trial in which the patient does not know what treatment they are receiving. And that is where we get stuck. We cannot compare them to microfracture surgery because the cartilage defects there are smaller. We also cannot compare them to the old therapy, because that required two operations, while our new therapy only requires one. And you cannot perform a sham operation; that is unethical. So we are currently not sure how to proceed."*

Finally, it is important that the hospital can provide the right circumstances for usage of the tissue engineered technology. An example was provided earlier by interviewee 13 whose skin tissue construct had specific requirements regarding the bandage that was used. If the specific type of bandage was not available in the hospital, the skin tissue construct was not going to be used (effectively). Another example of having the right circumstances is the availability of required complementary facilities, such as a cell culture facility. Interviewee 10 mentions that their cartilage repair therapy is currently bound to hospitals that have such facilities, which greatly reduces the spread of application of their therapy. Both the factors of coverage by insurance and the availability of the right circumstances can be regarded as providing clinicians with the right opportunities to use the technology.

4.2 Other user categories

As became apparent from the interviews, the user is not always (only) the clinician. In cases where the end user is the clinician, the decision to use the technology is likely to also involve other layers of organization before it gets there, e.g. insurance companies or the hospital purchasing department. In other cases the end user may be a company. For example, interviewee 1 mentioned that the end user of their human skin models are other companies that have a need to test their compounds. While these

other user categories have not been interviewed independently, the respondents that were interviewed are believed to have provided an accurate representation of the users. These other categories of users may have different beliefs about the consequences of technology usage and impediments to the process of technology usage, which will be discussed here.

4.2.1 Beliefs about expected consequences of technology usage (TAM)

The following paragraphs describe the factors that were reported by the interviewees as motivations why other user categories are likely to want to use upcoming tissue engineering technologies.

4.2.1.1 Perceived cost reduction

Tissue engineering products that are used by pharmaceutical companies are generally some sort of human organ or disease model which they employ as an additional way to test their compounds [I7, I14]. This supplementary information allows them to timely recognize failing therapies, stopping their development, and thus reducing their costs. For example, interviewee 1 mentions that the companies use their human skin model services in between preclinical and clinical trials as a way to further ensure that their compound will work within patients, enabling them to spot failing compounds before they make the large investment of going into very expensive clinical trials. The same holds true for future client companies of interviewee 11's human liver model. They will be able to test their compounds for liver toxicity, providing them with valuable insights on whether or not it will be feasible for use in vivo, thus giving them additional information on whether or not it is worth it to further develop and invest in the compound.

Similarly, interviewees 2 and 5 state that in general it is most important for hospitals that the implemented therapy is cost efficient. The same goes for the insurance company that eventually has to pay for most of the therapy [I5, I8]. Interviewee 8 mentions that this does not only relate to the price of the therapy, but also to the prevalence of the disease:

> *"It is more interesting for an insurance company if the therapy can be applied on a large scale, so on a large number of patients."*

4.2.1.2 Perceived ease-of-use

No matter the particular actor, whether it be the clinician, a pharmaceutical company, a supplier, or the producing company, actors within the industry want simple solutions [I2]. An example which was previously touched upon are the logistics that come with an autologous tissue engineered product. These procedures involve taking a biopsy from the patient and culturing the cells in a cell culture facility generally for up to several weeks. Whether this culturing happens in-house or at another company that provides these services, it requires a great deal of effort from both the clinician as well as the hospital itself. While this may be overlooked if the therapy greatly benefits the patient, interviewee 2 believes it proposes an insurmountable challenge, specifically because of the implications for the cost of the therapy which hospitals simply will not be able to cover.

4.2.2 Beliefs about expected impediments towards the process of technology usage (TT)

The following paragraphs describe the interviewees' perspectives on the potential impediments towards the process of upcoming tissue engineering technology usage as expected or experienced by other use categories.

4.2.2.1 Internal factors

Skills and abilities

In contrast to the clinicians, companies that use tissue engineering technologies do not necessarily have all the skills and abilities to effortlessly use the technology. As mentioned above, they generally use some sort of human organ or disease model for additional testing of their compounds. Interviewee 7 mentions, however, that these technologies are so complex that the companies generally cannot use these models themselves. Their lack of appropriate knowledge and skills thus refrains them from successfully using the technology. However, because the developers of this technology are aware of this, they offer to test the companies' compounds for them. So instead of directly using the technology, companies are enabled to use the services based on that technology.

Another factor that has been discussed earlier regarding the expected impediments towards the process of technology usage for clinicians is the availability of certain complementary technologies or facilities [10, I13]. While considered an external factor for clinicians, in the case of the hospital these facilities should be deemed internal. Although they might be constrained by budgetary conditions, it is in the ability of the hospital to make certain decisions regarding for example the type of bandage that is used. This may directly affect the chances of success of using certain types of tissue engineering technologies.

4.2.2.2 External factors

Opportunity

Similar to how clinicians are dependent on the budgetary choices a hospital makes, a hospital is dependent on the budgetary choices an insurance company makes. As mentioned before, hospitals are in essence a business entity and will therefore need to take good care with where they decide to spend their money. If an insurance company does not cover the specific therapy, it seriously limits their opportunity on using that therapy.

Otherwise, external factors seem to be of less importance to these user categories than to clinicians because of the difference in work environment. As interviewee 2 put it:

> *"Clinicians are not in charge of whether a new technology will be used; the purchasing department of the hospital is."*

While it is likely that clinicians will try and push for the use of certain technologies, in the end they are bound by the decisions that the hospital makes. At the same time, insurance companies, hospital purchasing departments, and pharmaceutical user companies are organizationally larger entities with more decisive power and are therefore less dependent on others' decisions.

4.3 Researchers and technology development

An altogether different but very prominent actor group are the researchers involved in tissue engineering. While they are not users of the technology, they play the central role in the development of tissue engineering technologies and are thus in part responsible for the availability of technologies for usage. Many of the respondents provided interesting insights into researchers' motivations and perceived difficulties in the technology development process. Similarly to clinicians, these factors can be subdivided into the TAM and TT concepts. However, instead of relating them to the behavior of technology usage, they should be related to the behavior of technology development. While the unit of analysis here differs from the rest of the research, i.e. researchers instead of users, these findings are again auxiliary to the

overall technology development and implementation process and can therefore be of interest to both researchers and practitioners. These factors will therefore be discussed presently.

4.3.1 Beliefs about expected consequences of technology development

The following paragraphs describe the factors that were reported by the interviewees as motivations why researchers are likely to involve themselves in the development of upcoming tissue engineering technologies.

4.3.1.1 Perceived usefulness

While not identical to the perceived usefulness of users per se, researchers also value the usefulness of their research very highly, specifically the ability to help patients. Interviewees 4, 6, 9 and 10 mention that the promise that what they are working on is eventually going to lead to a functional clinical application that is an improvement over current therapies is a great motivator. A good example is described by interviewee 10:

> *"There is a company in the Netherlands who do almost exactly the same thing as we do. Nevertheless, we decided to set up this research because we think this will eventually work better than what they are doing. Not in a competitive way, but more to help the patient."*

4.3.1.2 Intrinsic motivation

The intrinsic appreciation for doing research is a second, important motivation for researchers to concern themselves with tissue engineering technologies. The specific characteristic of being a multidiscipline research field, connecting multiple research areas and also the clinical aspect, seems to be the most common theme in that respect [I4, I6, I8, I9, I10]. Being able to apply creativity and crafting things also contributes to this motivation [I4, I8].

4.3.1.3 Job security

Furthermore, job security is important, meaning that if for a certain period funds are made available for a particular research line, researchers will appreciate this opportunity and look to take advantage of it [I5, I6].

The above motivations do not necessarily relate to tissue engineering specifically. Indeed, apart from the motivation of ultimately helping patients, the factors can really be considered to be general motivations for any researchers.

4.3.2 Beliefs about expected impediments towards the process of technology development

The following paragraphs describe the interviewees' perspectives on the potential impediments towards the process of upcoming tissue engineering technology development as expected or experienced by researchers.

4.3.2.1 Internal factors

Communication barriers

An important aspect to the development and the implementation of new tissue engineering products is that the parties that are involved need to overcome the barriers of communication that exist between people of different disciplines. Tissue engineering especially is a multidisciplinary field of research, combining the knowledge of cell biology, engineering and material scientists, and clinicians in order to create meaningful technologies. Many of the respondents touched upon the fact that researchers are not

aware of the possibilities and limitations of other disciplines, making it so that they might miss out on opportunities or that they lay out unworkable requests to their colleagues [I2, I7, I9, I14]. As interviewee 6 put it:

> *"You literally have to be able to take a look behind the scenes in order to know what is and what isn't possible."*

Additionally, as probably experienced more generally in translational research, researchers and companies also speak a different language. As interviewee 1 put it, researchers need to be aware that companies and investors usually have different connotations of what constitutes a good or promising result. If researchers are not aware of this they might set expectations too high, which then results in having to take the time to reconcile their relationships with their investors. This also holds true for researchers' interaction with the media. Interviewees 9 and 11 warn that some researchers, intentionally or not, may set unattainable expectations in the public. This can result in patients pulling out of other, similarly focused research because they believe that another solution is already developed, hurting the overall field of study and disappointing the patients when they eventually find out this is not the case. However, as interviewees 4, 5 and 6 put it, in the currently very competitive world of research it is sometimes necessary for a researcher to inflate the expectations in order to receive any funding at all.

Skills and abilities

Researchers need to be able to commercialize or secure future commercialization of the technology they are developing. However, interviewee 11 mentions that because usually the researcher itself is not an entrepreneur, he or she will have to find some sort of assistance in setting up things like intellectual property rights. This often requires the investment of time and sometimes money by the researcher, upon the work he or she is already doing for the research, which adds another barrier to the pursuit of bringing the technology to the market. Interviewee 1 describes how they took a different route by setting up a spin-off company to further manage the development and marketing of their skin tissue construct. Because development was still in conjunction with the academic hospital, day-to-day business included exchanges with clinicians, administrative staff, and the board of the hospital. This proved to be tedious however, since from the hospital's perspective there were no clear protocols on how they should deal with joint activities involving a commercial spin-off company. This resulted in a lot of confusion and hesitation from the hospital's side, especially due to the high turnover of employees which resulted in new employees having to delve into the case, and delayed the development of the technology significantly. Despite these difficulties, interviewee 12 contends that a researcher is required to think commercially in order to fund his research, something which relates to the inflation of expectations in order to secure funding.

4.3.2.2 External factors

Funding

The above mentioned difficulties in securing funding do not only relate to the researcher's own skills and abilities. Many of the interviewed researchers mention that overall it is becoming increasingly more difficult to secure funding for their research [I2, I4, I6, I8, I10, I11, I14]. While most agree this undoubtedly a consequence of the declining global economy, interviewee 11 also mentions that it is more notable in the life sciences field. He explains that in the event of a peer review of a project application, researchers in the life sciences are extremely critical compared to researchers from different, often competing

disciplines. This leads to life sciences projects losing out to projects from other disciplines and thus makes it even more difficult to secure funding.

Interviewees 4 and 14 mention that it is often required or at least advisable to show some proof-of-principle in order for investors to be interested in funding your research. However, according to interviewees 4 and 9, this can sometimes lead researchers to oversell their research to the public. In turn, this may result in the reluctance of funding bodies to finance research that is similar in nature. This is a problem because the oversold research promotes an application that does not work while other promising research becomes underfunded, eventually stagnating the development in the particular research area. Ultimately, however, it is advisable to attract commercial parties to your research, not only because they may directly fund your research but because of subsidies that become available when you collaborate with the industry [I10, I13].

Interviewee 10 adds, however, that even though funding absolutely becomes more difficult to acquire, she notices that this is a little less stringent for translational and applied research. Interviewee 12 even states that while he is aware of the struggles of his colleagues, his research team hardly has any problems securing funding. He explains:

> *"If we write down what disease the research is aimed at, there is no discussion. This is sometimes different for other fields such as orthopedics where alternative therapies exist and where the disease is not as life-threatening as heart failure. That does give us an advantage."*

Many of the interviewees that work at the University Medical Centre Utrecht (UMCU) mention that it has been important for them that UMCU has openly vocalized the priority for, among others, the regenerative medicine and stem cells research lines – which also covers tissue engineering [I8, I9, I10, I12]. Interviewee 8 states that it created legitimacy within the hospital, meaning research was more focused on these areas, in turn increasing the quality and breadth of the hospital's knowledge base as a whole on this subject. Combined with the new state-of-the-art facilities that UMCU has built specifically for the regenerative medicine research group it adds to the external reputation and therefore the likelihood of attracting external funds for their research. Interviewee 8 adds however that it is even more important to achieve a similar recognition of the whole field on a national and international level, as most funding is allocated on those levels.

Regulations

Almost all of the respondents highlight that it is difficult to obtain regulatory approval for their products. Interviewee 12 describes that because they work on the frontier of their science, regulatory authorities have a difficult time to categorize their products. It is a matter of figuring out in which category your research fits, while at the same time not even knowing for sure whether that category currently exists. Recent changes in regulations made by the FDA and the EMA have made it so that constructs using some type of human stem cell are now considered to be advanced therapy medicinal products (ATMPs) (European Parliament, 2007), meaning that to obtain regulatory approval, applicants now have to perform several clinical trials. Interviewee 1 mentioned that this has considerably delayed the market approval of their skin tissue construct. Additionally, the requirement of clinical trials necessitates additional funds, making it even more difficult to academically finance these types of research. Interviewees 2 and 4 underline the increase in duration and cost of the development process due to the introduction of the new regulations. Interviewees 8 and 12 mention that as a result, their research team tries to work with

already approved materials or materials that are most likely to obtain regulatory approval as much as possible, but this of course limits their options. The same goes for the protocols of cells they want to use. Disagreement exists on whether these difficulties would deter researchers from doing this type of research. Some say it is definitely unappealing to researchers [I8], while others argue that it is an essential part of the job of being a researcher [I6, I12].

Interviewee 6 adds that although regulations have become stricter, they do not necessarily lead to qualitatively better end products; it just delays their development. He argues for a change in mindset for the regulation of tissue engineering products that can be personalized to the specific patient. Because of this personalization, each end product will be slightly different, meaning they cannot be compared to traditional medicine which are standardized and the same for every patient. Therefore, interviewee 6 contends that the regulations for tissue engineering therapies and traditional medicine should not be comparable either. An example of where current regulatory methods prove to be insufficient for a tissue engineering therapy was touched upon in chapter 4.1.3.2. Interviewee 10 describes how their research team had difficulties setting up an adequate efficiency study for their one-step cartilage repair therapy because of the requirement to compare it to existing therapies in a blinded study.[2] However, the existing therapy consisted of two surgeries whereas their new treatment required only one surgery. This meant that in order to achieve a blinded study, they would have had to perform a sham surgery, something which is controversial and considered unethical by some (Miller, 2004). An alternative regulatory procedure has, however, not been identified yet. Interviewee 9 adds that for them it is also difficult to conduct a relevant efficiency study because it is often not possible to include many patients. As becomes apparent from these cases it remains difficult to ascertain how regulations should be arranged, something which is underlined by interviewee 6 as well.

Skepticism towards future success of tissue engineering

Finally, it is interesting to note that while many of the interviewed researchers do believe to various extents in the promise of their tissue engineering technologies, there are also other respondents including researchers that to various extents doubt whether tissue engineering will make good on its promise. The fact that it is exceptionally difficult to combine the different fields of research, both technology-wise as people-wise, upon the already extremely complex challenges within the individual contributing disciplines makes that the tissue engineering field progresses slowly. A specific concern that is voiced often is therefore whether there will be enough patience to support the field, or if investors and other funding agencies will sooner or later pull out [I2, I4, I5, I8, I12]. As interviewees 2 and 5 mention, tissue engineering is generally not yet a profitable option for companies, meaning they will not likely take over the research tasks that are currently mainly carried out by academic institutions. Interviewee 9 states:

> *"Maybe it is more of a scientific exercise rather than something which is going to produce a lot of workable applications in the near future."*

[2] "A study done in such a way that the patients or subjects do not know (is blinded as to) what treatment they are receiving to ensure that the results are not affected by a placebo effect (the power of suggestion)" (MedicineNet.com, 2015).

4.4 The basis of user beliefs

As becomes apparent from all of the above, beliefs do indeed play an important role in actors' expected consequences of and impediments towards technology usage or development. The following section will discuss what the important external factors are, i.e. on what information users base their beliefs. It starts with the different sources of information, as the data showed that the source of information depicts what kind of information is shared. It concludes with a summarizing overview on the different sources and subjects of information available to users.

4.4.1 Users' information sources

From the interviews it became clear that the specific source of information users relate to can also depict the content of the information that is shared. Therefore, this section will first describe the different information sources as put forward by the interviewees.

4.4.1.1 Interaction with researchers

One of the most apparent sources of information is the personal interaction users have with researchers. This can be facilitated in different manners. For example, interviewees 5, 6 and 9 mention that being close to the clinic as researchers means that it is easy to support day-to-day interactions with clinicians. Interviewees 2, 4 and 12 add that information is indeed exchanged and collaborations come into being from regular interaction in the corridors of the workplace. Many respondents mention that information exchange and collaborations generally happen in casual interactions, "no different from your normal social life" [I6]. In addition to connecting in shared workplaces, these interactions are facilitated e.g. at (scientific) meetings, presentations, seminars, graduate schools, and congresses [I2, I6, I8, I9, I12].

4.4.1.2 Interaction with collaborating researchers

A similar source of information is the personal interaction users can have with researchers in development collaborations. For example, interviewee 11 states that some of the clinicians they work with provide the tissue that they conduct their research with, meaning that they interact periodically. Interviewee 13 adds that clinicians involved in the development of their skin tissue construct are in constant contact with the researchers, which is stimulated by the fact that their entire research effort takes place at one location. This is underlined by interviewee 8 who has a jar on her desk from which clinicians come to take candy on a regular basis. As she put it:

> *"A lure, for the interaction."*

While these interactions are very similar to the interactions with regular researchers, the relationship between the two actors, the user and the researcher, is different. This also has consequences for the kind of information that is shared, which will be further elaborated upon later in this section.

4.4.1.3 Presentations and workshops by researchers

Mentioned before as facilitators for personal interaction, presentations and workshops given by researchers are also direct sources of information. Several interviewees mention that clinicians but also user companies gain direct information on technologies from attending presentations and workshops, mainly at congresses on their field of expertise [I2, I6, I11].

4.4.1.4 Presentations and workshops by companies

Similar to the presentations and workshops by researchers, clinicians and user companies are sometimes also directly invited to attend presentations by developer companies on their new technologies [I2, I5, I7,

I14]. These presentations and workshops seem to be a little bit different in the kind of information that is shared, however, which will be further elaborate upon later in this section.

4.4.1.5 Scientific journals and other specialized literature

The final source of information that appeared from the interviews are the scientific journals and other specialized literature which users read. Interviewee 2 mentions that clinicians that are employed by academic hospitals are also involved in medical research and are required to publish every now and then, meaning they need to stay up-to-date with the scientific literature in their field. Interviewee 11 underlines this by stating that their users read about their research in the respective specialized literature. However, he adds that clinicians have limited time to spend on these educational activities and are more likely to be interested in, e.g., the market introduction of new medicine than in fundamental research.

4.4.2 External factors

The sources of information set the backdrop for the kind of information that is shared. These important external factors will be discussed in this section. What is interesting to note here is that information on external impediments towards technology usage such as time for experimentation and the availability of necessary tools and facilities were not brought up by the interviewees. This is probably due to the fact that these factors are mostly dependent on the institution for which the user is employed, and knowledge of the institution itself is probably more present in the user itself than anywhere else.

4.4.2.1 Application of the technology

The most obvious type of information is knowledge about the application of the technology. Many of the interviewees reported that this is a part of all of their information exchanges [I2, I4, I5, I6, I9, I11, I12, I14]. It is also the only type of information that is shared regardless of the information source. In all likelihood, this is because it is unlikely that information on a technology is exchanged without having knowledge of what the technology is actually for. So for all other information exchanges, the application of the technology is an imperative component.

4.4.2.2 Efficacy

Another very prominent external factor is the efficacy of the tissue engineering technology [I2, I5, I6, I7, I9, I11, I12, I13, I14]. However, this type of information was not present in all information sources. Seemingly, researchers are more careful with presenting this type of information, publically conveying this only in scientific journals or other specialized literature, i.e. when enough proof has been gathered to justify a publication, and otherwise limiting it to the users they collaborate with. An example is provided by interviewee 11 who stated that for him it is too early, i.e. the evidence base is too small, to put out information towards potential future users.

On the contrary, developer companies do present this type of information also at their presentations and workshops for users [I2, I7, I14]. This is likely attributed to a different mindset, with companies focusing more on commercialization of their products for which efficacy is obviously important. It might also have to do with developer companies being further in their development process than researchers, having more validated evidence on the efficacy of their technology. The reason for this difference, however, did not become clear from the interviews.

4.4.2.3 Design characteristics

Both of the factors above also relate to the design characteristics of the technology. This in itself is, however, also an important type of information, specifically for users that are involved in the development

process [I4, I5, I8, I12, I13]. Indeed, many of the interviewees state that in their collaboration with clinicians, they exchange information on the design characteristics of their technologies, not only to inform the users, but also to obtain valuable knowledge on user requirements. Interviewees 4 and 5 underline that having clinicians provide the researchers with information on what they need and what a potential therapy should adhere to if it is to be used in the clinic and processing these requirements in their final product, is likely to create support among those clinicians for the usage of the product.

4.4.2.4 Timelines

Another factor that can be present in many of the information sources is the timeline of the technology, i.e. what the expectations are on further (refining) development [I6, I7, I14]. This is likely to be less relevant for technologies that already finished developing, but it is definitely applicable for technologies that are for example still in their clinical trials. For users that are included in these trials or for those who might be tempted to join these trials, it can be important to know when the technology is expected to enter the next phase or finish development. This way they know what to expect when it comes to the urgency of the implementation of the technology. The reason that this information is not prevalent in scientific journals and other specialized literature is probably because technological publications focus more on what is achieved then rather than speculating on what is to come. It should be noted, however, that this type of information was only reported by three of the interviewees, meaning that it might not be as prevalent as the other factors.

All of the abovementioned information sources and external factors are summarized in Table 2.

Table 2 Overview of the different information sources and subjects available to users.

Information source	Information subject
Available to all users	
Interaction with researchers (facilitated at, e.g., meetings, seminars, graduate schools, congresses, and the workplace in general) [I2, I4, I6, I8, I9, I12].	Application of the technology [I2, I6, I12, I14]; timelines [I6].
Presentations and workshops by researchers (at e.g., meetings, seminars, graduate schools, and congresses) [I2, I6, I8, I9, I10, I11, I12].	Application of the technology [I2, I4, I11]; timelines [I7, I14].
Presentations and workshops by companies [I2, I5, I7, I14].	Application of the technology [I2, I6]; efficacy [I2, I7, I14]; timelines [I7, I14].
Scientific journals and other specialized literature [I2, I6, I11].	Application of the technology [I2, I5, I6, I9, I11]; efficacy [I2, I5, I6, I9, I11].
Available to users participating in development and/or implementation efforts	
Interaction with collaborating researchers [I4, I5, I6, I8, I9, I11, I12, I13].	Application of the technology [I2, I6, I12, I14]; design characteristics of the technology [I4, I5, I8, I12, I13]; timelines [I6]; efficacy [I5, I12, I13].

4.4.3 The role of expectations

To determine the role of expectations in the belief formation process, the interviews were analyzed for connections between technological expectations and the abovementioned external factors. While it was difficult in the interviews to consistently assess whether respondents were referring to actual evidence or to their expectations, some general trends were discernable that will be discussed presently.

4.4.3.1 Expectations of efficacy

As touched upon before, researchers are sometimes compelled to tactfully overstate the results of their studies on the technology they are developing. Due to the increasing pressure on researchers, researchers' accounts on the results of these studies might sometimes also include researchers' future, positive expectations on the potency of the technology. Emphasis may be put on favorable efficacy data to boost the general optimism, increasing the researchers' opportunities for continuation of their research. Although this phenomenon was mainly reported in relation to securing funding for their research, it concerns the same information sources that users will refer to. Therefore, users are also exposed to these accounts of the expectations of developers.

When this type of information is exchanged in a personal meeting, e.g. at seminars or congresses, users might be aware of this perspective of the researcher and therefore tone down the information they take in. However, the research also suggests that published results may be affected similarly; sources which will generally be more trusted by users. It can therefore be argued that users knowingly or unknowingly base their beliefs of the efficacy of the technology, at least partially, on the expectations of the developers of the upcoming technology.

4.4.3.2 Expectations of timelines

Similar to the above, researchers are sometimes also compelled to overstate the timeline in which they can reach the end of the development of their technology. As interviewee 6 put it:

> *"In our view, it might take ten years to finish a research that in the end could lead to a product that improves the wellbeing of patients. However, when you file a subsidy request, the funding body will demand you do it in four or five years. So, that is what you'll promise. [...] We [researchers] all know how long it takes for a technology to work and to able to bring it to the market; it is longer than the couple of years for which you acquire funding."*

Again, this is likely to be less relevant for users of technologies that already finished developing, but it is definitely applicable for (potential) users of technologies that are still in their clinical trials. Their decisions on whether or not it is profitable for them to decide to use these technologies will in part depend on these timelines, for it dictates the moment in which they may eventually use the finished version of the technology. As it seems, users may base their ideas of these timelines on misrepresented accounts by researchers trying to secure funding.

Both of the above stated phenomena relate to making the technologies more attractive to actors that want to invest in it, both time (users) and money (funders). They are, however, not limited to the development of tissue engineering technologies. In fact, they seem to relate to any type of research that is concerned with the development of new medical therapies, as for example interviewee 6 recalled a similar situation in the "stem cell hype" that started in the late 1990s. This has also been shown in previous literature (e.g., Brown & Michael, 2003). It appears that researchers, mandated by external pressures or not and knowingly or unknowingly, draw on the social function of promises and expectations in technological developments to guide other actors into participating in their activities (see Figure 5).

5 Conclusions

This research has studied the theoretical concept of user beliefs of TAM and TT for the implementation of upcoming tissue engineering technologies, as well as explored the role of expectations in the foundation on which these user beliefs are based. The following section will summarize the findings and lay out the answer to the research question posed in the beginning of this research:

> *To what extent do users' technological expectations influence user acceptance in the implementation process of upcoming technologies in emerging technological fields?*

5.1 Testing user beliefs of TAM and TT for upcoming tissue engineering technologies

The literature provided a solid foundation for the characterization of the important concepts of beliefs of the TAM and TT models. For TAM, Davis et al. (1989) proposed that the perceived usefulness and perceived ease-of-use of a technology are the important beliefs about expected consequences of technology usage. For TT, Ajzen & Madden (1986) proposed that internal factors such as skills, abilities, knowledge, and adequate planning, and external factors such as time, opportunity, and dependence on the behavior of other people are the important beliefs about expected impediments towards the process of technology usage. Even though these concepts of beliefs were developed for the implementation of established (IT) technologies, the underlying thought that the implementation of a technology should have individual value is still relevant for upcoming technologies in emerging technological fields. Therefore, it was expected that the same concepts would also be important in the implementation of tissue engineering technologies.

The results have clearly shown that users who invest in a technology, either by helping its development or by using the developed product, do so because they believe it is useful to them and because it easily achievable for them. Almost none of the respondents found it necessary to further expand on these particular subjects beyond indicating that they are important aspects for users to use a technology. The absence of the urge for additional elaboration is actually a powerful indication of the self-evidence of these factors. The beliefs of perceived usefulness and perceived ease-of-use are therefore concluded to be important antecedents for user acceptance in the implementation of upcoming tissue engineering technologies. Hypothesis Ia is therefore accepted.

A little less distinct but also apparent was the importance of potential reputation and financial gain by being involved in the development of a promising technology. While not directly related to the actual use of a technology, these are important factors to consider for actors involved in the development of upcoming technologies in emerging technological fields.

For the beliefs about expected impediments towards technology usage, the external factors of time and opportunity were found to be important. Whether or not a user is provided with the right set of tools and facilities, and whether he is given the time to experiment with a new technology are both critical factors in the success of technology usage. The internal factors of skills and abilities were also found to be important to the success of technology usage. They are however currently not a limiting factor, because users are considered to be very skilled individuals. Because user beliefs about both internal and external factors are concluded to be antecedents for user acceptance in the implementation of upcoming tissue engineering technologies, hypothesis Ib is also accepted.

Following the above, this research is able to establish that the concepts of user beliefs of both the TAM and TT models are applicable to upcoming tissue engineering technologies. While this in itself is a valuable outcome, the following section will elaborate on the external factors that determine where the TAM and TT beliefs are based upon.

5.2 The basis of user beliefs and the role of expectations

While users involved in the implementation of established technologies will generally have access to information on the ins and outs of a technology and others' implementation experiences, users in the implementation of upcoming technologies in emerging technological fields will not have this available to them as these sources of information are still developing alongside the technology itself. The following step in this research has therefore been to determine what external factors are important in the belief formation process and to what extent technological expectations play a role in this.

The external factors that were found to be important to the formation of users' beliefs were the application of the technology, its efficacy, and the development timeline. Additionally, when users participate in the development process of the technology, users and developers may exchange the needs and possibilities for specific design criteria. The research also reported on the sources that supply these external factors. Important information exchanges happen mostly through interaction with researchers, whether through direct collaborations or through casual meetings at seminars or congresses. Presentations by researchers at such events also directly inform users, similarly to presentations or workshops by companies. Scientific journals and other specialized literature are another source of information.

These findings formed the backdrop for the analysis of the role of expectations in the formation of user beliefs, in which two general tendencies could be identified. First, expectations were found to be present in information about efficacy of the technology. Second, development timelines were contingent on skewed statements. Both phenomena are brought about by the actuality of technology developers needing to inflate their reports for the purpose of sustaining their research. Because users base their beliefs, at least partially, on these particular external factors and because these external factors are influenced by expectations, expectations can be seen as substituting for information that underlies the determinants of user beliefs in the implementation of upcoming tissue engineering technologies. Therefore, hypothesis II is also accepted.

The acceptance of this final hypothesis combined with the acceptance of the hypotheses Ia and Ib means that users' technological expectations are expected to influence user acceptance in the implementation process of upcoming technologies in emerging technological fields to some extent. Their role will be specifically related to affecting information exchanges with users regarding technologies' efficacy and development timelines.

5.3 The promise of tissue engineering

A final note should be made on the promise of the tissue engineering field as a whole.

This research has shown that while positive attributions are certainly present, skepticism of tissue engineering technologies is also evident. The complexity of the different disciplines and the troublesome course of combining these disciplines seems to have inhibited the field of making substantial progress over the last years. Coupled with the increasingly complex regulations making the development process significantly longer, and the increasing difficulty of securing funding, concerns are raised on the staying

power of the field. And while clever research methods may uphold the field for now, some assert that failing to keep the promises may eventually lead to a decline in the interest in the tissue engineering field and ultimately possibly its collapse.

If these concerns spread through the field and are subsequently adopted by the public, this would of course not only impact the potential tissue engineering technology users, but indeed the field as whole.

6 Discussion

This final chapter reflects on the quality of the research and possible limitations, as well as provide some insights into the implications of the research and possible future research objectives.

6.1 Research quality and limitations

6.1.1 External reliability

According to Bryman (2008: p. 376), it is "impossible to 'freeze' a social setting and the circumstances of an initial study to make it replicable". However, this research nevertheless aimed for the best possible replicability of the study by attempting to make the research steps as transparent as possible. The data collection chapter and Appendix B describe which general questions structured the interviews, and the transcripts which present the exact questions posed and answers received for each interview are available on request. While it cannot be guaranteed that the respondents would answer similarly to the same questions, there is also no reason to believe they would differ. The research also took care in carefully describing the methods of data preparation and analysis, ensuring that other researchers would be able to duplicate these steps. These factors should contribute to the replicability and therefore the external reliability of this research.

6.1.2 Internal validity

In order to assure a high quality of analyses, the data needed to be controlled for variations in reality (Bryman, 2008; Yin, 2003). This is especially relevant because of the differences between the discussed cases due to differences in the particular technologies. To ensure that outliers are controlled for and to reinforce the credibility of the data, triangulation was used where possible. When considering individual perspectives this was however not achievable, meaning that these results should be interpreted with care. It is worth mentioning here that even when certain findings did not come forward in certain cases, this does not necessarily mean that that finding did not apply there. Some of the findings emerged only after the final analysis, meaning it was not possible to further question other interviewees on these topics. This suggests that improvement can be made in the concurrence of the data collection and data analysis steps. Additionally, it should be noted that the theoretical relations between beliefs and attitudes, attitudes and behavioral intention, and behavioral intention and behavior, were not explicitly tested in this research, but instead were argued to be present based on existing literature (see Chapter 2.1.3). It would validate the resulting findings if future research could empirically establish these relations for implementation processes of upcoming technologies in emerging technological fields as well.

Furthermore, because of the nature of the theoretical concepts that were studied in this research, the obtained data was the interviewees' perceived truth of the situation rather than real observations. While this is unavoidable for this type of research subject, this does add some subjectivity to the data. This is especially important because the interviewees consisted mainly of researchers instead of actual (future) users of the technologies. Although these researchers provided a thorough assessment of the issues at hand, it is a subjective representation of the real issue. It would have added additional validation if a number of users could have verified the findings, something which future research should strive for. A recommendation of one of the interviewees that could be helpful in attaining enough interested users to participate in possible future research efforts is to also contact non-user clinicians, e.g., in peripheral hospitals.

6.1.3 External validity

Because of the qualitative nature of this research, rather than being directly generalizable, this research aimed for its results to be transferable based on theoretical grounds (Bryman, 2008). To this end, purposive sampling was used to sample for a tight fit between theory and research objects. This means that cases were selected for which it was clear that the technology in question was upcoming, in the tissue engineering field, and that it had specific (future) users. The variety in the particular tissue engineering technologies that were studied, and the triangulation of these cases, provides more valid insights for this field as a whole. While the aim for the findings of this research was transferability, this research facilitates some generalization of the results by providing a detailed description of case profiles, interview quotes, and the studied theoretical relations, making it easier to compare the results with other empirical instances of upcoming technologies in emerging technological fields.

6.2 Implications

Although extensively validated for the implementation of established technologies (Benbasat & Barki, 2007; Davis et al., 1989; King & He, 2006; Mathieson, 1991; Taylor & Todd, 1995), this research has shown that Davis et al.' (1989) technology acceptance model and Bagozzi et al.' (1992) theory of trying also have their value in predicting user behavior in the process of implementing upcoming technologies in emerging technological fields. For implementers of these technologies this adds another tool for them to evaluate their implementation processes and guide managerial interventions aimed at reducing the problem of underused technologies due to non-acceptance of users. Based on a vast body of literature, Venkatesh & Bala (2008) put forward multiple interventions aimed at improving three determinants of user acceptance: (i) creating favorable ease-of-use perceptions (e.g., design characteristics, user participation, training, and peer support); (ii) influencing the determinants of perceived usefulness (e.g., design characteristics, user participation, incentive alignment, training, organizational and peer support); and (iii) working on users' reactions to business process changes (e.g., user participation, peer support, and management support). There is no reason to assume that these interventions will be inadequate for implementation of upcoming technologies, therefore implementers could utilize these interventions to the benefit of their success.

Additionally, the notion that expectations may substitute for other types of information in the formation of user beliefs helps implementers and users alike to better understand what information is important for user acceptance of emerging technologies. While there has been literature dedicated to the establishment of shared expectations and the influences to this process, it is lesser known how to influence expectations on an individual level (Alkemade & Suurs, 2012; Bakker, van Lente, & Meeus, 2012; Budde et al., 2012). Implementers could, however, employ strategies targeting shared expectations in order to influence individual expectations, as we know that individual expectations are continuously adjusted to the broadly shared, collective expectations (Konrad, 2006). Important to these strategies are statements about the certainty of the technology in question. These statements are vital to the process of reconfiguring and building the networks of actors (regulatory, economic, scientific, public) that engage in the development of the technology (Brown & Michael, 2003; Geels & Smit, 2000; Van Lente & Rip, 1998). Implementers would do well to be mindful about their statements regarding the technology and to explicate them as well as possible. The research has shown the important sources of information that implementers should focus on when doing so, i.e. personal interaction, presentations and workshops, and scientific journals and other specialized literature. However, it is unlikely that a single implementer could influence the technological landscape to a large extent. Instead, it might be more valuable for implementers to

recognize that individual users have their own expectations about the particular implemented technology, and to use this knowledge in fostering their interventions.

6.3 Future research

In addition to the quality improvements proposed earlier, future research might also seek to explore other, related research directions.

First of all, while it is argued on thorough theoretical basis that the fundamental sequence of beliefs → attitudes → intentions → behavior is likely to be consistent for implementation of upcoming technologies in emerging technological fields, it should be further validated through a quantitative analysis. In a similar manner, quantitative analysis of the proposed beliefs is needed to further establish the robustness of the findings. Additionally, as has been done in previous studies of the TAM and TT models (Ahuja & Thatcher, 2005; Kim et al., 2009; King & He, 2006; Venkatesh & Bala, 2008), it is important to know the importance of the individual beliefs; what factors influence user attitudes and therefore their intentions and behavior the greatest. All of the above points could potentially be combined in one quantitative study. Such a study would require a larger sample in order to infer meaningful, quantitative correlations. These insights would, however, allow implementers to direct their interventions better and more efficiently, focusing on the most important factors.

Furthermore, while this research has laid out the groundwork for the relation between technological expectations and the external factors that influence the determinants of user beliefs, it is as of yet still an abstract theoretical implication. Additional research is needed to further explore the role of expectations and to comprehensively establish its effect on external factors. One point can be to compare it to the formation process of individual expectations. User beliefs specifically about the usefulness and ease-of-use of a technology—both are expectations of the use of the technology—can be argued to be contained in the notion of individual technological expectations. Konrad (2006) stated that the formation of these individual expectations is based on the exchange of expectations in interactions with many others, meaning they are continuously adjusted to the specific expectations of other actors and to the broadly shared, collective expectations. The process this research proposed (expectations → external factors → determinants → beliefs), however, has a linear approach to the formation of individual expectations or beliefs. It would be interesting to study whether this linearity is legitimate, for example because of the specific type of expectations (about technology usage), or whether belief formation is actually more akin to the overall formation of individual expectations and thus more interactive. Another point is that this research has focused on users that are or have someway been involved in upcoming technologies. It would be interesting to find out whether similar findings would hold true for users that are unfamiliar. Studies have shown that the proximity to the scientific work that is done can affect the (un)certainty of the 'facts' that are produced (Brown & Michael, 2003). It is argued that uncertainty is more acute for actors who are close to the point of knowledge production, because they experience the contingencies of knowledge production which makes them cautious, and outsiders or competitors, because they critique knowledge on moral, economic or political grounds rather than technical grounds. Users are in between these extremes, being too far from the point of knowledge production to experience all its contingencies, but involved close enough to estimate the potential benefits a technology can have for them and not oppose it on other grounds. Therefore, they are argued to have a diminished capability to be cautious or uncertain about expectations. It would be interesting to know whether the findings of this research regarding the

effect of expectations on the external factors of efficacy and timelines is in part due to this 'naivety' of users, or if it stands true regardless of the proximity of users to the production of knowledge.

A final research direction that is indirectly related to user acceptance is the sustainability of the field, in this case, specifically the tissue engineering field. Many of the respondents talked about the inflation of results in order to secure funding, i.e. developers using expectations to convince other actors of the value of their research. Some also questioned the sustainability of this practice, and it seems rightfully so. Literature has shown that failure to deliver on hyped promises and expectations has severely damaged the reputation and credibility of technology fields in the past (Bakker et al., 2012; Brown & Michael, 2003; Ruef & Markard, 2010). Several studies have underlined that this is also a concern in the tissue engineering field (Auger, Badylak, & Bell, 2006; Oerlemans, Van Hoek, Van Leeuwen, & Dekkers, 2014). Clear and validated resolutions towards this issue are, however, not yet developed. From a realist, economical view, it is assumed these hype—disappointment cycles are caused by a calculable difference between the expectations and the real value of a technology, such that expectations can rationally be adjusted (Brown & Michael, 2003). Theoretical efforts such as roadmapping might assist in preventing disappointment by toning down hyped expectations through contrasting hype with technology typical challenges that can be anticipated (Robinson & Propp, 2008). Oerlemans et al. (2014) suggest that researchers should be more modest while communicating about an ultimate goal. However, Brown & Michael (2003) propose that the 'real value of a technology' is interrelated with the expectations we have of that technology and therefore it is not as easy as 'simply' adjusting the expectations. Ruef & Markard (2010) describe the hype—disappointment cycle around stationary fuel cells and show the importance of the presence of two institutionalization processes: stable and constantly positive framing of the technology, and emerging institutional structures leading to increasing positive externalities, for the continuation of innovation activities in the field. How these perspectives relate to the tissue engineering field is, however, speculation. Therefore, to ensure the sustainability of the field, future research efforts should be focused on exploring methods to counteract the expected decline of the tissue engineering field.

Appendix A – Case and interviewee descriptions

Below is a description of the interviewees, including their function, the type of organization they belong to, and what technology they are involved with.

I*	Function	Type of organization	Technology
1	Project coordinator	Developer company	Autologous skin constructs and human skin models.
2	Professor, researcher	University	Several polymer materials used in tissue engineering technologies.
3	Professor, pediatric urologist, researcher	Academic hospital	Several urogenital tissue engineering and regenerative medicine technologies.
4	Researcher	Academic hospital	Tissue engineering constructs aimed at treating congenital urological defects through tissue (in)growth.
5	Professor, researcher	Academic hospital	Tissue engineering and regenerative medicine technologies for osteoarthritis, specifically a full, permanent meniscus implant.
6	Professor, researcher	Academic hospital	Several cardiovascular regenerative medicine technologies.
7	President clinical advisory board	Public-private partnership	Human organ and disease models.
8	Associate professor, researcher, coordinator of regenerative medicine Master's programme	Academic hospital	Several cartilage and bone regeneration technologies for craniomaxillofacial applications.
9	Postdoctoral researcher	Academic hospital	Tissue engineered sources of urethra tissue for use in urethral reconstruction.
10	Postdoctoral researcher	Academic hospital	One-step tissue engineering therapy for cartilage defects, specifically in the knee.
11	Assistant professor, researcher	University	3D-printed liver for use as a human liver model.
12	Assistant professor, researcher	Academic hospital	Several tissue engineering and regenerative medicine technologies for cardiac regeneration.
13	Researcher	Academic hospital	Autologous skin constructs.
14	Internist, researcher	Developer company	Human organ and disease models, specifically related to cancer diagnostics.

** I = interviewer.*

Appendix B – Interview questions

The interviewees were questioned on three different topics: technology characteristics, users' beliefs, and users' appropriation of information. The following structure was used as a general guideline, but most interviews deviated from it in one way or another. In the end, however, it was made sure that all the topics were sufficiently covered.

Technology characteristics

1. What is the current/future application of the implemented technology?
2. What is the current/future market for the implemented technology?
3. What is the current/future value of the implemented technology?

Users' beliefs

Questions regarding technology usage:

1. What are the rationales to use the technology?

In some interviews it was necessary to further specify what was meant with this question by providing examples. If so, the following questions would generally be asked:

2. What do you believe, is the usefulness of the technology?
3. What do you believe, is the ease-of-use of the technology?

Questions regarding the goal pursuit of usage (trying to use):

1. What are the difficulties in the process of developing and implementing the technology?

Again, in some interviews it was necessary to further specify what was meant with this question by providing examples. If so, the following questions would generally be asked:

2. What do you believe the consequences of successful technology usage will be?
3. What do you believe the consequences of failing at using the technology will be?
4. How do you view the process of usage? Would you say it is easy or difficult to follow through?

External factors: information appropriation and expectations

1. How do users come into contact with the technology?
2. On what information do users base their judgments of the technology?

References

Agarwal, R. (2000). Individual Acceptance of Information Technologies. In R. W. Zmud (Ed.), *Framing the Domains of IT Management Research: Glimpsing the Future through the Past* (pp. 85–104). Pinnaflex, Cincinnati, OH.

Ahuja, M. K., & Thatcher, J. B. (2005). Moving beyond intentions and toward the theory of trying: effects of work environment and gender on post-adoption information technology use. *MIS Quarterly*, *29*(3), 427–459.

Ajzen, I., & Fishbein, M. (1980). *Understanding attitudes and predicting social behaviour*. Englewood Cliffs, NJ: Prentice-Hall.

Ajzen, I., & Madden, T. J. (1986). Prediction of goal-directed behavior: Attitudes, intentions, and perceived behavioral control. *Journal of Experimental Social Psychology*, *22*, 453–474.

Alkemade, F., & Suurs, R. A. A. (2012). Patterns of expectations for emerging sustainable technologies. *Technological Forecasting and Social Change*, *79*(3), 448–456.

Al-Senaidi, S., Lin, L., & Poirot, J. (2009). Barriers to adopting technology for teaching and learning in Oman. *Computers and Education*, *53*(3), 575–590.

Auger, F., Badylak, S., & Bell, E. (2006). Tissue Engineering: The Hope, the Hype, and the Future. *Tissue Engineering*, *12*(5), 1143–1150.

Bagozzi, R. P. (2007). The Legacy of the Technology Acceptance Model and a Proposal for a Paradigm Shift. *Journal of the Association for Information Systems*, *8*(4), 244–254.

Bagozzi, R. P., Davis, F. D., & Warshaw, P. R. (1992). Development and test of a theory of technological learning and usage. *Human Relations*, *45*(7), 659–686.

Bakker, S., Van Lente, H., & Meeus, M. (2011). Arenas of expectations for hydrogen technologies. *Technological Forecasting and Social Change*, *78*(1), 152–162.

Bakker, S., van Lente, H., & Meeus, M. T. H. (2012). Credible expectations - The US Department of Energy's Hydrogen Program as enactor and selector of hydrogen technologies. *Technological Forecasting and Social Change*, *79*(6), 1059–1071.

Balogun, J., & Hope Hailey, V. (2008). *Exploring Strategic Change* (3rd ed.). Pearson Education.

Barki, H., Titah, R., & Boffo, C. (2007). Information System Use–Related Activity: An Expanded Behavioral Conceptualization of Individual-Level Information System Use. *Information Systems Research*, *18*(2), 173–192.

Bay, D., & Daniel, H. (2003). The theory of trying and goal-directed behavior: The effect of moving up the hierarchy of goals. *Psychology and Marketing*, *20*(8), 669–684.

Beer, M., & Nohria, N. (2000). *Breaking the Code of Change*. Harvard Business Press.

Benbasat, I., & Barki, H. (2007). Quo vadis, TAM? *Journal of the Association for Information Systems*, *8*(4), 211–218.

BenMessaoud, C., Kharrazi, H., & MacDorman, K. F. (2011). Facilitators and barriers to adopting robotic-assisted surgery: Contextualizing the unified theory of acceptance and use of technology. *PLoS ONE*, *6*(1), e16395.

Bergek, A., Jacobsson, S., Carlsson, B., Lindmark, S., & Rickne, A. (2008). Analyzing the functional dynamics of technological innovation systems: A scheme of analysis. *Research Policy*, *37*, 407–429.

Bhattacherjee, A. (1998). Management of emerging technologies: Experiences and lessons learned at US West. *Information & Management*, *33*(5), 263–272.

Borup, M., Brown, N., Konrad, K., & Van Lente, H. (2006). The sociology of expectations in science and technology, *18*(3-4), 37–41.

Brown, N., & Michael, M. (2003). A sociology of expectations: Retrospecting prospects and prospecting retrospects, (March 2015), 37–41.

Bryman, A. (2008). *Social Research Methods* (3rd ed.). Oxford: Oxford University Press.

Budde, B., Alkemade, F., & Weber, K. M. (2012). Expectations as a key to understanding actor strategies in the field of fuel cell and hydrogen vehicles. *Technological Forecasting and Social Change*, *79*(6), 1072–1083.

Burnes, B. (2004). *Managing Change: A Strategic Approach to Organisational Dynamics* (Fourth Edi). Pearson Education.

Camarinha-Matos, L. M., Tschammer, V., & Afsarmanesh, H. (2004). On emerging technologies for VO. In L. M. Camarinha-Matos & H. Afsarmanesh (Eds.), *Collaborative Networked Organizations - Research Agenda for Emerging Business Models* (pp. 207–224). Kluwer Academic Publishers.

CIRM. (2012). Engineering Strategies, Opportunities, and Challenges for Tissue Repair and Regeneration: CIRM Workshop Summary and Recommendations. San Fransisco, CA.

Collingridge, D. (1980). *The social control of technology*. London: Pinter.

Damschroder, L. J., Aron, D. C., Keith, R. E., Kirsh, S. R., Alexander, J. A., & Lowery, J. C. (2009). Fostering implementation of health services research findings into practice: a consolidated framework for advancing implementation science. *Implementation Science*, *4*, Article 50.

Davidson, A. R., & Morrison, D. M. (1983). Predicting contraceptive behavior from attitudes: A comparison of within- versus across-subjects procedures. *Journal of Personality and Social Psychology*, *45*(5), 997–1009.

Davis, F. D. (1986). *A technology acceptance model for empirically testing new end-user information systems: Theory and results*. Massachusetts Institute of Technology.

Davis, F. D., Bagozzi, R. P., & Warshaw, P. R. (1989). User acceptance of computer technology: a comparison of two theoretical models. *Management Science*, *35*(8), 982–1003.

Day, G., Schoemaker, P., & Gunther, R. (2004). Wharton on managing emerging technologies.

Edmondson, A. C., Bohmer, R. M., & Pisano, G. P. (2001). Disrupted routines: Team learning and new technology implementation in hospitals. *Administrative Science Quarterly*, *46*(4), 685–716.

Eisenhardt, K. M. (1989). Building Theories from Case Study Research. *Academy of Management Review*.

European Parliament. (2007). European Parliament Legislative Resolution of 25 April 2007 on the Proposal for a Regulation of the European Parliament and of the Council on Advanced Therapy Medicinal Products and Amending Directive 2001/83/EC and Regulation (EC) No 726/2004 (COM(2005)0. Strasbourg, April 25, 2007: European Parliament.

Fishbein, M., & Ajzen, I. (1975). *Belief, attitude, intention and behavior: an introduction to theory and research*.

Fisher, M. B., & Mauck, R. L. (2013). Tissue engineering and regenerative medicine: recent innovations and the transition to translation. *Tissue Engineering. Part B, Reviews*, *19*(1), 1–13.

Freedman, V. A., Calkins, M., DeRosier, R., & Van Haitsma, K. (2005). *Barriers to implementing technology in residential long-term care settings*.

Freeman, C., & Soete, L. (1997). *The economics of industrial innovation*.

Geels, F. W., & Smit, W. a. (2000). Failed technology futures: Pitfalls and lessons from a historical survey. *Futures*, *32*, 867–885.

Greenhalgh, T., Robert, G., Bate, P., Macfarlane, F., & Kyriakidou, O. (2008). *Diffusion of Innovations in Health Service Organisations: A Systematic Literature Review*. John Wiley & Sons.

Hekkert, M. P., Suurs, R. a a, Negro, S. O., Kuhlmann, S., & Smits, R. E. H. M. (2007). Functions of innovation systems: A new approach for analysing technological change. *Technological Forecasting and Social Change*, *74*, 413–432.

Henderson, R. M., & Clark, K. B. (1990). Architectural Innovation: The Reconfiguration of Existing Product Technologies and the Failure of Established Firms. *Administrative Science Quarterly*, *35*(1), 9–30.

Hew, K. F., & Brush, T. (2007). Integrating technology into K-12 teaching and learning: Current knowledge gaps and recommendations for future research. *Educational Technology Research and Development*, *55*, 223–252.

Horch, R. E. (2012). New Developments and Trends in Tissue Engineering: An Update. *Journal of Tissue Science & Engineering*, *3*(2), 1000e110.

Igbaria, M., Guimaraes, T., & Davis, G. B. (1995). Testing the determinants of microcomputer usage via a structural equation model. *Journal of Management Information Systems*, *11*(4), 87–114.

Jaccard, J. J., Knox, R., & Brinberg, D. (1979). Prediction of behavior from beliefs: An extension and test of a subjective probability model. *Journal of Personality and Social Psychology*, *37*(7), 1239–1248.

Karsh, B.-T. (2004). Beyond usability: designing effective technology implementation systems to promote patient safety. *Quality & Safety in Health Care*, *13*, 388–394.

Kim, Y. J., Chun, J. U., & Song, J. (2009). Investigating the role of attitude in technology acceptance from an attitude strength perspective. *International Journal of Information Management*, *29*(1), 67–77.

Kimberly, J. R., & Evanisko, M. J. (1981). Organizational Innovation: The Influence of Individual, Organizational, and Contextual Factors on Hospital Adoption of Technological and Andministrative Innovations. *The Academy of Management Journal*, *24*(4), 689–713.

King, W. R., & He, J. (2006). A meta-analysis of the technology acceptance model. *Information & Management*, *43*, 740–755.

Klein, K. J., & Knight, A. P. (2005). Innovation Implementation: Overcoming the Challenge. *Current Directions in Psychological Science*, *14*(5), 243–247.

Konrad, K. (2006). The social dynamics of expectations: The interaction of collective and actor-specific expectations on electronic commerce and interactive television. *Technology Analysis & Strategic Management*, *18*(3-4), 429–444.

Lanza, R., Langer, R., & Vacanti, J. P. (Eds.). (2011). *Principles of Tissue Engineering*. Academic press.

Lederer, A. L., Maupin, D. J., Sena, M. P., & Zhuang, Y. (2000). The technology acceptance model and the World Wide Web. *Decision Support Systems*, *29*(3), 269–282.

Lee, Y., Kozar, K. a., & Larsen, K. R. T. (2003). The Technology Acceptance Model: Past, Present, and Future. *Communications of the Association for Information Systems*, *12*(50), 752–780.

Levitt, B., & March, J. (1988). Organizational Learning. *Annual Review of Sociology*, *14*, 319–340.

Luo, X., Li, H., Zhang, J., & Shim, J. P. (2010). Examining multi-dimensional trust and multi-faceted risk in initial acceptance of emerging technologies: An empirical study of mobile banking services. *Decision Support Systems*, *49*(2), 222–234.

Mathieson, K. (1991). Predicting User Intentions: Comparing the Technology Acceptance Model with the Theory of Planned Behavior. *Information Systems Research*, *2*(3), 173–191.

MedicineNet.com. (2015). Definition of Blinded study.

Metzker, M. L. (2005). Emerging technologies in DNA sequencing. *Genome Res.*, *15*(12), 1767–76.

Miller, F. G. (2004). Sham surgery: an ethical analysis. *Science and Engineering Ethics*, *10*(1), 157–66.

Nelson, R. R., & Winter, S. G. (1982). *An Evolutionary Theory of Economic Change*.

Novosel, E. C., Kleinhans, C., & Kluger, P. J. (2011). Vascularization is the key challenge in tissue engineering. *Advanced Drug Delivery Reviews*, *63*(4-5), 300–11.

O'Neill, K., Singh, G., & O'Donoghue, J. (2004). Implementing eLearning Programmes for Higher Education: A Review of the Literature. *Journal of Information Technology Education*, *3*, 313–323.

Oerlemans, A. J. M., Van Hoek, M. E. C., Van Leeuwen, E., & Dekkers, W. J. M. (2014). Hype and expectations in tissue engineering. *Regenerative Medicine*, *9*(1), 113–122.

Orlikowski, W. J. (2000). Using Technology and Constituting Structures: A Practice Lens for Studying Technology in Organizations. *Organization Science*, *11*(4), 404–428.

Paton, R., & McCalman, J. (2008). *Change management: A guide to effective implementation* (Third edit). SAGE.

Porter, M. E. (1998). *The competitive advantage of nations* (2nd ed.). New York: Palgrave Macmillan.

Robinson, D. K. R., & Propp, T. (2008). Multi-path mapping for alignment strategies in emerging science and technologies. *Technological Forecasting and Social Change*, *75*, 517–538.

Rogers, P. L. (2000). Barriers to Adopting Emerging Technologies in Education. *Journal of Educational Computing Research*, *22*(4), 455–472.

Ruef, A., & Markard, J. (2010). What happens after a hype? How changing expectations affected innovation activities in the case of stationary fuel cells. *Technology Analysis & Strategic Management*, *22*(3), 317–338.

Schot, J., & Geels, F. W. (2008). Strategic niche management and sustainable innovation journeys: theory, findings, research agenda, and policy. *Technology Analysis & Strategic Management*, *20*(5), 537–554.

Sheppard, B. H., Hartwick, J., & Warshaw, P. R. (1988). The Theory of Reasoned Past Action : Meta-Analysis of with Modifications for Recommendations and. *Journal of Consumer Research*, *15*(3), 325–343.

Strauss, A. L., & Corbin, J. M. (1990). *Basics of Qualitative Research: Grounded Theory Procedures and Techniques*. Newbury Park, California: Sage.

Taylor, S., & Todd, P. A. (1995). Understanding information technology usage: A test of competing models. *Information Systems Research*, *6*(2), 144–176.

Tester, M., & Langridge, P. (2010). Breeding technologies to increase crop production in a changing world. *Science*, *327*(5967), 818–822.

Tushman, M. L., & Anderson, P. (1986). Technological Discontinuities and Organizational Environments. *Administrative Science Quarterly*, *31*(3), 439–465.

Utterback, J. (1996). *Mastering the dynamics of innovation*.

Van Lente, H. (1993). *Promising technology: the dynamics of expectations in technological developments*.

Van Lente, H., & Rip, A. (1998). Expectations in Technological Developments: an Example of Prospective Structures to be Filled in by Agency. In C. Disco & B. J. R. Van der Meulen (Eds.), *Getting New Technologies Together. Studies in Making Sociotechnical Order* (pp. 203–229). Berlin: Walter de Gruyter.

Venkatesh, V., & Bala, H. (2008). Technology acceptance model 3 and a research agenda on interventions. *Decision Sciences*, *39*(2), 273–315.

Venkatesh, V., & Davis, F. D. (1996). A model of the antecedents of perceived ease of use: Development and test. *Decision Sciences*, *27*(3), 451–481.

Yin, R. K. (2003). *Case Study Research: Design and Methods* (3rd ed.). London: SAGE Publications.

Zint, M. (2002). Comparing three attitude-behavior theories for predicting science teachers' intentions. *Journal of Research in Science Teaching*, *39*(9), 819–844.