



Designing business model development tools for sustainability—a design science study

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Received: 29 July 2020 / Accepted: 16 February 2021 / Published online: 12 March 2021
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Abstract

The development of business models that boost fundamental changes in behavior to act more economically, ecologically, and socially is a challenging task because the consideration of sustainability is a multidimensional problem characterized by uncertainty and value conflicts. In order to deal with such complex tasks, methodological and technical tool support is required. Even though tools for business model development are well-established, they typically focus on economic obligations and pay little attention to ecological and social concerns. To bridge this gap, we shed light on the question of how functions for software can be designed to respect sustainability in business models. We present a software prototype and prescriptive design knowledge in the form of design principles and features, and thereby aim to contribute to the information systems body of knowledge by providing guidance to software designers and business model developers on how to reflect on sustainability.

Keywords Software-based tools · Canvas-based tools · Sustainability · Design science · Reflection

JEL classifications O3 · Q5 · M14

Introduction

Current trends due to climate change and the rising global population and its increased consumption of (natural) resources present fundamental challenges that require extensive changes (Brundtland et al. 1987). Organizations need to transform themselves into more sustainable entities that seek to fulfill new demands such as being environmentally friendly or complying with regulations (Butler 2011; Hanelt et al. 2017; Melville 2010). Therefore, organizations are adopting the triple bottom line-principle (Elkington 1997), which means that they reflect on their activities in terms of environmental and social responsibility, in addition to their economic obligations (Seidel et al. 2017). A major boost for organizational transformations is the development of more sustainability-oriented business models (Schaltegger et al. 2016), which premise radical innovations

(Nidumolu et al. 2009). However, while today's businesses still focus on economic-oriented outcomes (Perić et al. 2017), an investigation is needed into how they can simultaneously create environmental, social, and economic values (Massa et al. 2017)—thus broadening the scope of traditional business model values (Bouwman et al. 2020).

In attempting to support business model development, research and practice have provided a wide range of tools (e.g., Bouwman et al. 2012; Heikkilä et al. 2016) such as the business model canvas (BMC), the service-technology-organization-finance (STOF) framework (Bouwman et al. 2008) or the BM cube (Lindgren and Rasmussen 2013). Since adjacent fields such as creativity support (Wang and Nickerson 2017), product development (Mauerhoefer et al. 2017), and process modeling (Recker 2012) have highlighted the positive effects of employing software, research on business models has also started to explore these possibilities. In doing this, researchers have highlighted the great potential of business model development tools (BMDTs) (e.g., Osterwalder and Pigneur 2013; Veit et al. 2014) and practitioners have argued that business model design and implementation could benefit significantly from software (Terrenghi et al. 2017). BMDTs enable business models to be digitally represented, edited, and analyzed, and therefore can facilitate certain actions such as collaborating, documenting, and assessing more

Responsible Editor: Ulrike E. Lechner

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efficiently than the ‘pen & paper’ versions (Ebel et al. 2016; Osterwalder et al. 2005). Moreover, by employing software, several stakeholders can participate in business projects regardless of time and location (Chesbrough 2007; Terrenghi et al. 2017).

However, although BMDTs have gained popularity, they are still in an emerging stage and have several shortcomings: first, available BMDTs differ considerably in their functions, and thus support a heterogeneous set of development activities (Szopinski et al. 2019). Second, we lack comprehensive knowledge concerning which functions BMDTs should provide to support developing business models in general (e.g., Ebel et al. 2016) as well as in the context of sustainability (e.g., methods and software “*are increasingly in demand but still rare*”, Geissdoerfer et al. 2016, p. 1219). Third, available decision support for business models tends to focus on financial data (e.g., Dellermann et al. 2019) for which reason the integration of aspects relating to sustainability is limited. In consequence, large parts of the potential benefits remain untapped (Athanasopoulou and de Reuver 2018; Szopinski 2019). To bridge this gap, the purpose of this study is to describe prescriptive knowledge for software that assists both tool designers in (re-)designing BMDTs and users in reflecting on sustainability. We formulate the key question of this study as follows: *How can functions for business model development tools be designed to support reflecting sustainability in business models?*

To answer this question, we conduct a design science research (DSR) study in which we present (1) design knowledge that can be employed for (re-)designing BMDTs—particularly those that rely on canvas-based modeling approaches—and (2) a software prototype that helps to represent and analyze sustainability in business models. We aim to present specific functionality for software-based tools that enable sustainability to be reflected in business models; we do not aim to investigate every function such as exporting files, importing data, or saving projects (for an overview, see Szopinski et al. 2019). In doing this, we seek to respond to recent calls for an investigation into how to design BMDTs, advance the field of business model development in terms of assessing and visualizing sustainability, and furthermore to complement the existing body of knowledge on how to use information systems (IS) for sustainability-oriented transformations. We primarily focus on the development perspective, which means that business model developers should be able to make more informed decisions. Nonetheless, we believe that tool support is also relevant for customers who, for instance, can analyze business models and make more informed purchase decisions.

Research background

Business models and sustainability

The increasing uncertainty and dynamic of the market force businesses to continuously innovate their **business models**

(Casadesus-Masanell and Ricart 2010; Chesbrough 2002), which is emphasized by diverse disciplines such as information systems (Al-Debei and Avison 2010), entrepreneurship (George and Bock 2011), and strategy management (Massa et al. 2017). In broad terms, a ‘business model’ poses a blueprint of a firm’s logic to create, distribute, and capture value (Haaker et al. 2017). Following Magretta (2002, p. 4), a business model answers: “*Who is the customer? And what does the customer value? [...] How do we make money in this business? What is the underlying economic logic that explains how we can deliver value [...]?*” In addition to that obligatory economic views, sustainable organizations attempt to achieve an integration of social and ecological values too (Massa et al. 2017; Nidumolu et al. 2009). However, today’s business models still focus on profit maximization (Schaltegger et al. 2016) for which reason academics and practitioners are increasingly concerned with the design and implementation of business models that generate financial profits as well as benefits for the environment and society (Massa et al. 2017). **Sustainability** refers to the “*development that meets the needs of the present without compromising the ability of future generations*” (Brundtland et al. 1987, p. 43). To make this broad concept more manageable, this article follows the well-established differentiation of economic (e.g., financial success), ecological (e.g., benefits for the natural environment), and social (e.g., benefits for employees) sustainability (Elkington 1997).

Although the integration of both concepts—**business models and sustainability**—is still an emerging field, different authors have contributed to the understanding of it (e.g., Boons and Lüdeke-Freund 2013; Bocken et al. 2014; Stubbs and Cocklin 2008). According to Schaltegger et al. (2016, p. 6), a business model for sustainability should capture “*economic value while maintaining or regenerating natural, social, and economic capital beyond its organizational boundaries.*” In this vein, further authors have emphasized that these business models,¹ for instance, “*express [their] purpose, vision, and/or mission in terms of social, environmental, and economic outcomes*” (Stubbs and Cocklin 2008, p. 121). This requires a holistic reflection on how a business operationalizes its strategy (Lozano 2018) and substantial changes of almost every aspect within an organization (Nidumolu et al. 2009) such as the value proposition, suppliers, and financial model (Boons and Lüdeke-Freund 2013). Therefore, appropriate tools are required that assist in performing such transformations.

¹ The combination of both sustainability and business models is denoted by a variety of terms, for instance, ‘business models for sustainability’ (Schaltegger et al. 2016), ‘sustainable business models’ (Stubbs and Cocklin 2008), and ‘sustainability-oriented business model’ (Lüdeke-Freund et al. 2017). Beside some specifics, these concepts all aim to balance economic, ecological, and social sustainability. This study primarily uses ‘sustainability-oriented business model’.

Tools for business model development

To respond to the demands for methodological and technical support on business models (Voigt et al. 2013), a range of analog and digital tools² has been proposed (e.g., Bouwman et al. 2012; Bouwman et al. 2020; Heikkilä et al. 2016; Szopinski et al. 2019). These tools seek to support different stages and activities of business model development, for instance, the *design phase* through mostly business model ontologies (Bouwman et al. 2008; Osterwalder and Pigneur 2010; Gordijn and Akkermans 2001), the *implementing phase* through combining ontology-based business model tools with process model tools (Schoormann et al. 2020), the *evaluation phase* through financial-based decision support systems (Daas et al. 2013), the *experimentation phase* through stress-testing tools seeking to find answers in terms of the robustness of a business model (Bouwman et al. 2012; Haaker et al. 2017), or *finance activities* through business plans and cost-benefit analysis. In this study, we follow prior research by adopting the view that the BMC has become the quasi-standard for business model development (Massa et al. 2017), and we therefore take canvas-based tools in particular into account. Nonetheless, although these approaches are well-applied in academia and practice, they do not necessarily focus on sustainability (Bocken et al. 2015) and are insufficient to create the required sustainability-oriented transformations (Schaltegger et al. 2016). This is also indicated by the fact that there is still a lack of agreement on the fundamental components that should be included to formally represent sustainability in business models (Massa et al. 2017). Moreover, Terrenghi et al. (2017) concluded from several interviews with business model experts that such canvases need to be flexible so that users can adapt and/or integrate them with additional frameworks to fulfill specific purposes.

In line with adjacent streams of research which share similarities to the task of business model development, like creativity support systems, new product development, and process modeling, business model research has also started to explore software support (e.g., Athanasopoulou and de Reuver 2018; Szopinski et al. 2019; Veit et al. 2014). Software, for instance, has great potential in enhancing the innovation process and helping to create better value propositions (Hanelt et al. 2015). As these tools are digital, they may assist their users in performing certain (and additional) actions more efficiently than with the ‘pen & paper’ versions. Some of the positive effects of using software tools include consistency of the model, visual navigation, support of collaboration, creativity, documentation, and assessment (Ebel et al. 2016; Fritscher and

Pigneur 2014; Osterwalder and Pigneur 2013). In attempting to respond to the demands for such tools, researchers have presented software support that mostly emphasizes a certain perspective such as finance, creativity, or collaboration among a team of developers. These include for example: a creativity support system for business modeling including functions such as ‘shared idea editor’ and communication (Voigt et al. 2013); a prototype for business model exploration seeking to identify relevant components via a canvas-based approach implemented in Microsoft Excel (Athanasopoulou and de Reuver 2018); a spreadsheet-based decision support system for financial assessment (Daas et al. 2013); a spreadsheet-based stress-testing tool to verify the business model’s robustness (Haaker et al. 2017); a decision support system for business model validation (Dellermann et al. 2019); a tool for enhancing the business model comprehension (Augenstein and Fleig 2018). Besides focusing on a certain facet of business model development, a limited number of studies aim at providing holistic design-relevant knowledge and software support. As an example, Ebel et al. (2016) derived 20 functions for collaboration in particular and other attempts have sought to replicate the sticky note experience from ‘pen & paper’ (e.g., Fritscher and Pigneur 2010). However, to leverage the full potential of software-supported business model development, academia and practice have called for an investigation into how to ensure practice-oriented tooling (Bouwman et al. 2020) since the application of such tools is often complex (Heikkilä et al. 2016) as well as theoretically-grounded design knowledge for BMDTs to determine which functions are suitable to best support business model development (Szopinski et al. 2019; Veit et al. 2014). Moreover, current tooling tends to focus on financial data (Dellermann et al. 2019; Schoormann et al. 2018), which is not sufficient to address multiple dimensions of sustainability.

In consequence, we need approaches that enable (1) sustainability-oriented aspects to be considered in the visualization of business models and (2) business model elements and components to be assessed in terms of ecological and social concerns, as well as (3) knowledge to be derived on how to design BMDTs and their functions for sustainability.

Reflection theory

When individuals face problems of uncertainty and value conflict, it is difficult to find adequate solutions because individuals cannot make sense of such situations and cannot consider all consequences that might occur from certain activities (Schön 1983). In attempting to cope with this, intuitive reflection is applied that reveals tacit knowledge, and thus helps to handle complex problems (Schön 1983). Reflection typically comprises steps for gathering experiences, re-assessing them based on the current problem (e.g., enable assumptions to be examined), and deducing learnings for the future (Boud et al.

² Comprehensive overviews of software tools for business models can be found, for example, in: Szopinski et al. (2019) who reviewed 24 BMDTs, BusinessMakeOver (www.businessmakeover.eu), Business Model Toolbox (www.bmtoolbox.net).

1985; Kolb 1984; van Woerkom and Croon 2008). This process is especially helpful, for instance, when managers face novel challenges for which they do not have mental models. Whereas reflection is often performed individually, there are several benefits from joint reflection such as being inspired by experiences from others (Daudelin 1996) and creating ideas that go beyond an individual's knowledge (Renner et al. 2019). Referring to this study's context of sustainability-oriented business models, several aspects are comparable to reflection such as business model developers (1) face design situations of value conflict in which they have to balance economic, ecological, and social aspects (e.g., Joyce and Paquin 2016), (2) have to manage potential consequences to specify subsequent actions (e.g., Breuer et al. 2018), and (3) cannot make sense of the entire design situation at once (i.e., business model and its environment). Furthermore, the literature on reflection emphasized that (4) reflection is essential for design activities (Schön 1992; Renner et al. 2016) as well as that (5) software can assist reflection because it enables to store prototypes, recognize design consequences, and extend the ability to construct and explore situations (Prilla 2015; Schön 1992), which are both relevant for our context too. Furthermore, reflection has been employed in studies on sustainability and/or business models such as Lozano (2018) who has emphasized reflection in his definition for sustainable business models ("*holistic and systemic reflection of how a company operationalizes its strategy*", p. 1164), Cucuzzella (2016) who has explored design approaches and tools for sustainable development and pointed out the relevance of reflective thinking, or Duijn (2018) who has found out that "*reflection helps to identify the possibilities for improvement and guides their targeted implementation in practice*" (p. 34). Based on those similarities and potential benefits, we employ 'reflection theory' to underpin the development of this study's artifacts—we are however aware that other approaches might also be helpful (see Discussion).

Method

Design science helps to create novel artifacts (Gregor and Hevner 2013), which is appropriate for investigating IT support for business model development (Augenstein and Mädche 2017; Veit et al. 2014; Daas et al. 2013). For deriving design knowledge, we employ the iterative DSR methodology (DSRM) as proposed by Peffers et al. (2007). The DSRM differentiates between six phases for the identification of a problem, definition of objectives, design and development, demonstration, evaluation, and communication. We adopted

this but merged demonstration and evaluation because they are closely interweaved in our study. Overall, we ran through three major design cycles,³ over approximately three years, of building and evaluating our artifact (Fig. 1).

In **design cycle 1**, based on an extensive analysis of BMDTs and literature related to sustainability-oriented business models, our study started with an awareness of one major problem (see Research Background): the lack of comprehensible design knowledge of software functions that best support reflecting sustainability in business models. Consequently, the purpose of this study is to provide prescriptions on the development of BMDTs that support sustainability-oriented reflection. To provide a solution, we built on reflection theory that helps to justify the technical design (Gregor and Jones 2007). Furthermore, we made use of related studies to consider general requirements and existing knowledge from business model research. As a result, a tentative design was proposed. In the design and development phase, we carried out prototyping sessions to integrate potential users and their needs already at an early stage. Prototyping is a useful approach for designing such artifacts because it facilitates the generation of a multitude of ideas (Gregory and Muntermann 2014). Referring to this study, 32 participants in five interdisciplinary groups with knowledge related to sustainability and business model development were randomly formed. These groups developed low-fidelity prototypes that provide functions for instantiating the initial design solution. The participants had 90 min to examine sustainability-related effects in a specific case. For demonstration and evaluation, the results of each group were discussed with all participants and three researchers in a follow-up workshop (i.e., each prototype was presented by indicating the results of representing sustainability as well as by reflecting the applicability of the design solution).

Based on the analysis of the first cycle, in **design cycle 2**, a refined design solution was suggested. Similar to the cycle before, the adjusted solution was instantiated in prototyping sessions with 41 participants in five groups who were not involved in the first iteration. Again, low-fidelity prototypes were developed. For the purpose of evaluation, we held a workshop with the participants and three researchers to discuss and consolidate the findings. As participants in both cycles 1 and 2, we selected graduate students enrolled in a Master's-level IS course at a public university on a voluntary basis because this allowed us to recruit people who (a) have a basic understanding of the topic—comparable to users engaging in business model workshops—and (b) might act as consultant or founder of companies in future, thus being part of such tool's target group as well as (c) to obtain a relatively large sample size with reasonable effort (e.g., Meth et al. 2015).

³ For details on how the design solutions has been refined across the three design cycles, please refer to Appendix 3 and Appendix 4.

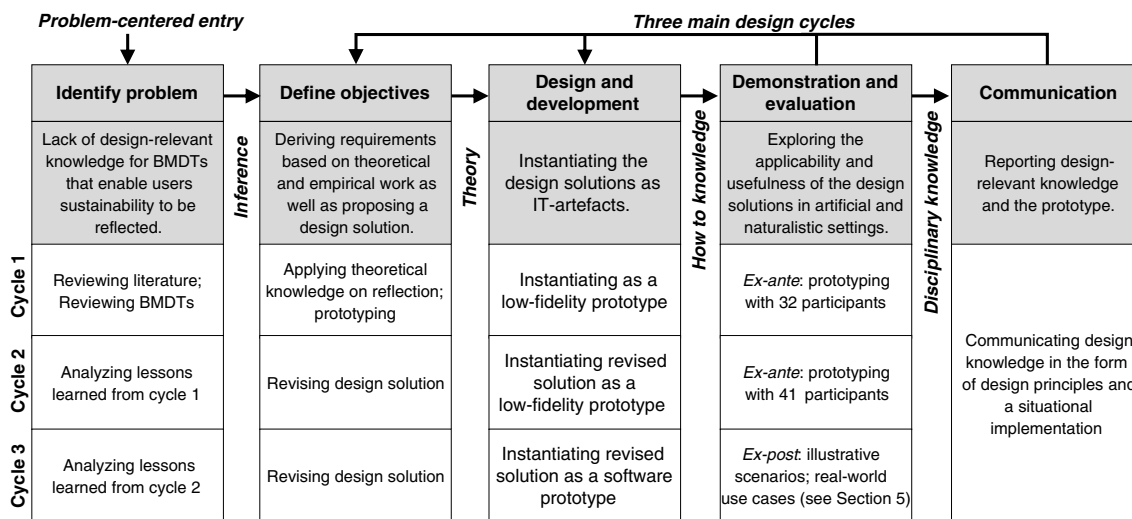


Fig. 1 Research approach (adapted from Peffers et al. 2007)

In **design cycle 3**, we consolidated the entire knowledge gathered during the cycles with three researchers, which again led to the design solution’s adjustment. Based on this, we suggested a revised solution, which is implemented in the form of a web-based software prototype. For evaluation, we performed several evaluation episodes (**Demonstration and evaluation** section) including employing the software in use cases with industry partners.

Following Gregory and Muntermann (2014), in each cycle, the author team sought to employ mechanisms for *abstraction* (i.e., what can we learn for the larger problem class allowing to incorporate sustainability in business model development) and *de-abstraction* (i.e., how can we transfer the abstract theoretical body of knowledge to the particular instantiation) to reflect on the deduced findings.

Artifact description

In the following part, we first describe and justify the design principles (DP) and, afterward, translate them into design features (DF) (see the differentiation of principles and features in Meth et al. 2015).

Derivation of design principles

Business model research has emphasized the need for a shared representation which can be seen by, for example, Ebel et al. (2016) who argued that a standardized template should be provided, or Fritscher and Pigneur (2014) who stated that software should enable creating own semantic meanings of visual representations. Visualization tools have been determined as the main tool for developing and analyzing business models (e.g., Osterwalder and Pigneur 2010; Täuscher and Abdelkafi 2017) for which reason business model modeling

languages (BMMLs) are proposed that help organizing business models (John et al. 2017). However, since sustainability-oriented business models differ from traditional ones (e.g., because of a broader notion of value and multi-stakeholder perspective, Massa et al. 2017), it is still doubtful whether available BMMLs are appropriate to represent sustainability. Schaltegger et al. (2013), for instance, have called for research on “*how do business models for sustainability extend established business model concepts like Osterwalder and Pigneur’s Business Model Canvas [..]?*”. Responding to this—also in line with insights non-sustainability-oriented business model development (e.g., “organizations adapt these frameworks to their specific needs”, Terrenghi et al. 2017, p. 977)—, customizations have been proposed that provide additional semantics to incorporate sustainability in business models (see Schoormann et al. 2016 for an overview of customizations). Whereas some of these customizations address the redesign of an entire BMML (e.g., Joyce and Paquin 2016), others focus on rather separated semantics (e.g., Kanshieva 2012). Nonetheless, to allow reflecting sustainability, information and experiences need to be visible to create a common ground (Daudelin 1996), acting as a ‘boundary object’ (Bouwman et al. 2020). If information is articulated, designers can make sense of the world and can invent innovative moves (Schön 1992), which is also important in attempting to achieve more sustainability. Accordingly: *Provide functions for integrating sustainability-oriented semantics into business model modeling languages in order for users to represent economic, ecological, and social aspects in business models. (DPI).*

Once relevant information is articulated, aspects of sustainability can be examined. As this is a complex and multidimensional issue, users need guidance on how to start with the analysis. Following reflection theory, asking critical questions and facing actors with basic assumptions, such as prevailing

norms and values, helps to prohibit stagnation (van Woerkom and Croon 2008), structures situations (Hatton and Smith 1995), and guides the reflection's process (Renner et al. 2016). Adapting this concept to this study's context, questions in terms of sustainability should be highlighted by, for example, emphasizing approaches such as the 17 Sustainable Development Goals (United Nations 2019), sustainability strategies such as sufficiency, consistency, and efficiency (Huber 2000), elements of a business model with a sustainability lens (Boons and Lüdeke-Freund 2013), or more specific triggers (e.g., ask whether renewable resources are used). This contributes to a continuous comparison of the business model elements at hand against sustainable concepts, and thus helps to identify improvement potential and get ideas for the (re-)design of the current model. Accordingly: *Provide functions for highlighting sustainability-oriented key questions, concepts, and strategies that enforce sustainability in order for users to compare and take potentially relevant aspects into account. (DP2).*

Generally, when being confronted with complex situations, designers make use of their (mental) repertoires of prototypes obtained from earlier experiences (Schön 1992). Referring to business models, the literature also has suggested considering variants and configurable concepts during the design of new solutions by, for example, employing business model archetypes and taxonomies (e.g., Bocken et al. 2014; Gimpel et al. 2018) or business model patterns (Gassmann et al. 2014). These provide repertoires of business model (element) descriptions that are proven solutions to typical problems occurring during the design of business models (Remane et al. 2017). Since about 90% of all business model innovations are based on recombining existing patterns (Gassmann et al. 2014), such approaches are a powerful tool. Furthermore, there is an evolving research stream on sustainable business model patterns such as Lüdeke-Freund et al. (2018) who derived a set of sustainable patterns including ecological patterns (e.g., maximize energy efficiency, substitute with renewable resources), closing loop patterns (e.g., online waste exchange, product recycling), and community patterns (e.g., substitute ownership through sharing businesses) or Zeiss (2019) who deduced circular economy practices. Accordingly: *Provide functions for incorporating sustainability-oriented best practices and alternative solutions in order for users to systematically get ideas and impulses for redesigning current business models. (DP3).*

After getting first ideas for refinement, the sustainability impact of possible design choices needs to be estimated (see also Haaker et al. 2017)—for instance, deciding between resources that are scarce available or resources that are renewable changes the business model's impact on the environment. For reflection, it is essential to explore possible consequences from a certain activity, which has been emphasized by Schön (1992, p. 6) who argued that “in the absence of such

qualitative judgments [...] designing would have no thrust or direction [*and thus*] would be entirely unmotivated”. Following this, assessing business model elements and its potential alternatives is a crucial task that enables to identify positive impacts (e.g., the business model's key activities consider fair working conditions) as well as negative impacts (e.g., the business model's key resources require a lot of rarely available materials) (e.g., Lüdeke-Freund et al. 2017). By designing alternative business model variants, developers are able to disclose their tacit and implicit knowledge to solve practical problems (Schön 1983), which assists to plan future actions. Accordingly: *Provide functions for collecting and judging sustainability-oriented impacts of a business model (element) in order for users to identify improvement needs and to plan future efforts. (DP4).*

In order to collect potential impacts and to judge them, it may help to lay filters on a current situation that reduces the complexity of dealing with multidimensional or so-called wicked problems (List 2006). As humans have a limited information-processing capacity, they typically cannot consider all perspectives and information at once for which reason it is helpful to start with examining a situation using one particular perspective and to successively take additional perspectives into account (Schön 1992)—divide and conquer a problem. Sustainability is also a multidimensional concept (Elkington 1997), which should be divided into smaller, more manageable parts. Moreover, sustainability-oriented business models are influenced by several internal and external stakeholders (e.g., employees, suppliers, and customers) who have specific views on the model that need to be respected (Stubbs and Cocklin 2008). Therefore, the modeling process should consider different perspectives within a collaboration (Breuer et al. 2018). Accordingly: *Provide functions for specifying sustainability-relevant perspectives on business models in order for users to handle the multidimensional issue of sustainability and incorporate stakeholders' points of view. (DP5).*

Translation of design principles into design features

Since DPs are typically free from technical descriptions (Morana et al. 2014), we translate them into design features (DF) that constitute one way of instantiating the design knowledge (see Table 1).

As a first step, users typically make use of BMMLs to structure a business model project. Prior research has indicated that the BMC has become the quasi-standard (e.g., Massa et al. 2017) for which reason we implemented features for selecting the BMC as an underlying BMML but also for creating additional BMMLs (*DF1*). Since such canvases need to be flexible (Terrenghi et al. 2017), several adaptations are available seeking to represent semantics for specific domains and needs. To enable sustainability-relevant semantics to be considered, features for customizing BMMLs are provided

Table 1 Mapping of design principles and design features

Design principles	Design features
DP1: Provide functions for integrating sustainability-oriented semantics into business model modeling languages in order for users to represent economic, ecological, and social aspects in business models.	- DF1: Select between pre-defined BMMLs such as BMC as an underlying structure of a business model project. - DF2: Adapt and customize available BMMLs. - DF3: Link business model elements and components. - DF4: Switch between 'template'-'sticky note'-modus.
DP2: Provide functions for highlighting sustainability-oriented key questions, concepts, and strategies that enforce sustainability in order for users to compare and take potentially relevant aspects into account.	- DF5: Provide checklists with strategies, key questions, concepts, and goals for sustainability. - DF6: Mark items that have been used/discussed. - DF7: Highlight items that best possible fit a certain business model element/component.
DP3: Provide functions for incorporating sustainability-oriented best practices and alternative solutions in order for users to systematically get ideas and impulses for redesigning current business models.	- DF8: Integrate business model taxonomies to provide domain-specific knowledge, best practices, variants, and a set of alternative solutions. - DF9: Search and filter across the taxonomies as well as transfer selected characteristics to the business model.
DP4: Provide functions for collecting and judging sustainability-oriented impacts of a business model (element) in order for users to identify improvement needs and to plan future efforts	- DF10: Provide a trade-off analysis to collect, discuss, and weigh up possible consequences. - DF11: Indicate for each business model element if there are more positive or negative aspects collected. - DF12: Track and justify design decisions for each element.
DP5: Provide functions for specifying sustainability-relevant perspectives on business models in order for users to handle the multidimensional issue of sustainability and incorporate stakeholders' points of view.	- DF13: Provide tabs with different views (e.g., economic, ecological, and social sustainability). - DF14: Invite (external) users/experts. - DF15: Provide a discussion board. - DF16: Comment specific business model elements.

(Schoormann et al. 2016) including, for instance, adding additional components for social and environmental impacts, splitting the component for 'cost structure' into financial and social costs, renaming the component 'revenue stream' into donations to respect Non-Governmental Organizations (**DF2**), as well as linking elements to visualize dependencies (**DF3**). Also, we implemented a feature for switching between 'template-modus' (i.e., working on the underlying BMML) and 'sticky note-modus' (i.e., working on the actual business model) (**DF4**).

To provide additional information such as key concepts that reinforce sustainability, checklists are implemented that draw on general concepts and questions for ecological (e.g., closed-loop production, renewable resources), social (e.g., local jobs, fair trade), and economic sustainability (e.g., compliance) as well as overall goals such as proposed by the 17 Sustainable Goals (United Nations 2019; Schoormann and Kutzner 2020) (**DF5**). As emphasized during the ex-ante evaluations, it is helpful to enable users to mark which items have been employed or at least discussed (**DF6**). Furthermore, checklist items that best possible fit a certain business model

element or component should be highlighted (e.g., when designing the 'key resources', emphasize concepts that deal 'renewable materials') for which reason we tagged items to assign them to a specific component and sustainability dimension (**DF7**).

By making use of domain-specific knowledge, impulses for improvement and alternative concepts can be presented for a specific business model domain. Therefore, the software implements a repertoire of existing characteristics (i.e., business model elements) utilizing business model taxonomies that help to organize domain knowledge (Nickerson et al. 2013) such as for Carsharing business models (Remane et al. 2016). These taxonomies allow users to get inspiration on available solution concepts, for instance, in the case of a Carsharing business model, users can choose between alternative drives such as electric, diesel, gas, and hybrid (**DF8**). Also, users can search and filter for characteristics (i.e., elements) across the entire repertoire of taxonomies as well as can transfer selected characteristics to the business model project (**DF9**).

For managing consequences, based on the evaluations and a literature review on sustainability-oriented assessment

strategies, we decided to implement a *comparison-oriented assessment* in the form of a *trade-off analysis* (Schoormann et al. 2018). This allows users to unrestrictedly collect and discuss positive and negative consequences in terms of sustainability. In implementing this, we attempt to overcome challenges with assessment strategies that take a lot of effort such as calculating possible effects of single actions, and thus, aim at providing an approach that is easy to employ during business model development (**DF10**). This is also in line with Terrenghi et al. (2017) who pointed out that companies use BMMLs, for example, to “spot and rank the most critical elements” (p. 978). We further visualize if there are more positive or negative aspects collected for a business model element so that improvement potential is highlighted (**DF11**) as well as allow tracking reasons for the (re-)design of elements in the form of an ‘element history’ so that users can retrace the evolution of certain elements (**DF12**).

As sustainability is often divided into economic, ecological, and social dimensions (Elkington 1997), we provide features to differentiate between these three perspectives by default as well as to extend this by adding individual perspectives to a business model. These perspectives can be controlled via tabs such as in a web-browser (**DF13**). Because collaboration plays a key role in reflecting sustainability (e.g., in the form of sharing (critical) opinions), features for user invitations to allow obtaining feedback from external actors (e.g., to validate specific ideas) (**DF14**) as well as for a discussion board (**DF15**) to store feedback and leave comments that enable business model developers disclosing information and sharing thoughts are implemented (**DF16**).

Demonstration and evaluation

Expository instantiation

After proposing generalized design knowledge, it has to be “brought into being” (Gregor and Jones 2007, p. 328). Therefore, we present our implemented prototype, the ‘Green Business Modeling Editor’ (Fig. 2; business model based on Knackstedt et al. 2019) that instantiated the proposed design solution: top left, the main modeling area with the BMC as an underlying BMML and different customizations; the perspective editor that enables clicking through different views as well as to specifying additional views. Top right, checklists are highlighted to force thinking about and comparing the model with sustainable concepts. Bottom left, an exemplary taxonomy editor enables the selection of specific characteristics. Center right, trade-off analysis for assessing business model components and elements by collecting positive and negative aspects. Bottom right, fostering collaboration and feedback via, for example, a discussion board.

The prototype is intended to be employed for developing new business models as well as analyzing existing business models, and furthermore for considering economic, ecological, and social sustainability. For best possible support (see also evaluation results), the tool can be used in facilitated sessions with a group of people interested and knowledgeable in a certain business model. The procedure for applying the tool can be divided into several steps—which we also observed during the participant sessions: first, comparable to other approaches (e.g., Haaker et al. 2017), the business model needs to be described for a visualized understanding such as by utilizing the BMC. Second, users try to indicate what is good and what is bad in terms of sustainability by collecting ideas, statements, and opinions through the trade-off analysis. It is therefore valuable to have a diverse team with different backgrounds and views is valuable. Third, the good/bad aspects can be visualized by making use of the customizations of the original canvas. Fourth, when improvement potential is disclosed, users can be inspired by (a) checklists that emphasize sustainable concepts and strategies as well as (b) business model taxonomies for refinement. Fifth, alternative variants and ideas can be discussed again within and beyond the team (e.g., external stakeholder).

Ex-post evaluation episodes

Design researchers should conduct multiple evaluation episodes throughout their design (Sonnenberg and vom Brocke 2012a; Venable et al. 2016) to, for example, with a varying set of functions to address challenges in the context of evaluating software which is characterized by a large space of instantiating theoretical constructs (Lukyanenko et al. 2015). Following this, we performed several ex-post evaluations (for ex-ante evaluation, see Method) in different settings (e.g., with varying functions, participants, usage purposes). In doing so, we primarily seek to validate the practical relevance in terms of helping to solve business problems and the applicability of our design solution in real contexts (Table 2) (see Appendix 5 for more details).

Drawing on diverse documents such as verbal protocols (e.g., from interviews with industry partners), results from the workshops (e.g., business model results), changelog files (e.g., created from participants to justify their design decisions), and observations (e.g., created from external researchers during the workshops), we deduced several insights for the developed artifact. Next, we present these insights—sorted according to the derived DPs.

Referring to the first principle (**DPI**) of adapting BMMLs, two main observations emerged: first, after selecting an underlying business model structure, customizations are used frequently to represent sustainability-relevant aspects. This is indicated, for example, by the fact that 4/5 groups in Episode 3 employed at least one of the customizations (e.g., splitting the

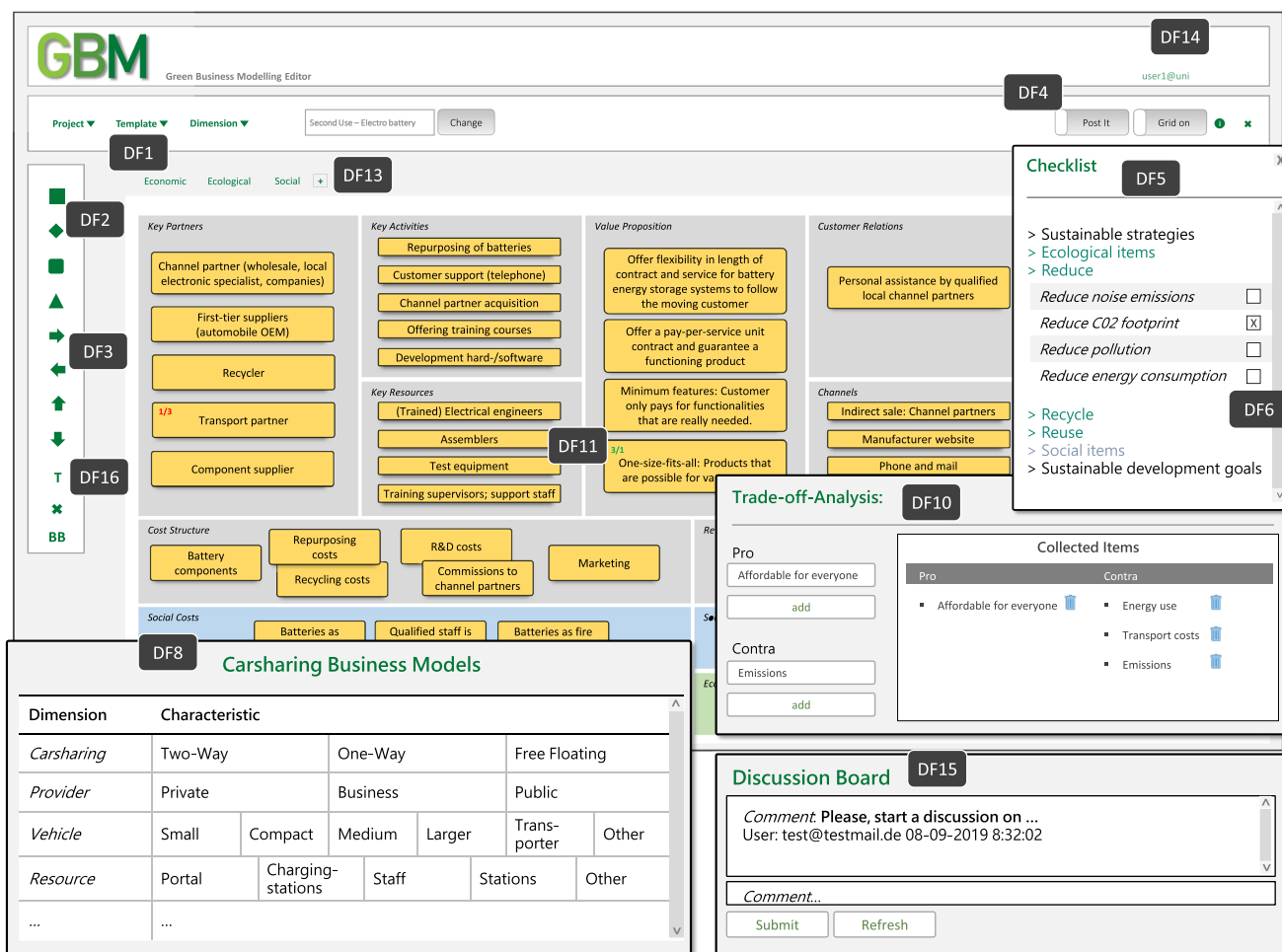


Fig. 2 Software prototype ‘Green Business Modeling Editor’ and design features

Table 2 Ex-post evaluation episodes

ID	Description / [participants]	Goal(s)
E1	Workshop (1/2 day) to develop sustainability-oriented business models. [1 researcher*, 5 students]	Software applicability through user feedback.
E2	Bachelor’s-level course (four months) to develop business models for electric mobility. [3 researchers*, 3 students]	Software applicability through user feedback across a period.
E3	Master’s-level workshop (three sessions each 90 min) to reflect on a business model from an industry partner (Green IT). [19 students in five groups, one CEO]	Software applicability, completeness of functions through feedback from users and practitioners.
E4	Master’s-level workshop to reflect on a business model from industry partner (Sharing economy) (90 min); development of a sharing business model (three sessions each 90 min). [18 students in four groups, one CEO]	Software applicability, completeness of functions through feedback from users and practitioners.
E5	Workshop (1/2 day) to collectively reflect on a partner’s business model (water industry). [2 researchers, 5 practitioners]	Software feasibility, (preliminary) usefulness through a naturalistic case.
E6	Workshop (two sessions each 180 min) to collectively reflect on a partner’s business model (kiln industry), to create new ideas. [2 researchers, 6 practitioners]	Software feasibility, (preliminary) usefulness through a naturalistic case.

*= at least one researcher was not involved in building this study’s artifact

component for the value proposition into economic and environmental value) and participant's statements such as "[...] we adopted the established canvas, which leverages the consideration of additional aspects for sustainability". Second, collaboratively visualizing the business model and discussing what sustainability aspects should be highlighted in the canvas (i.e., through which customizations) did help to create an enhanced understanding of the model, and thus, deriving new ideas for the future redesign—especially observed in the practitioner workshop in Episode 5.

Second, we observed that providing sustainability-oriented checklists such as with key concepts (**DP2**) can support both the generation of new ideas and the identification of improvement potential by reflecting on current elements against best practices and guiding questions. The relevance of this principle is emphasized, for example, by statements such as "[...] providing lists with key aspects and questions is very helpful because, so, we are continuously motivated to reflect on different sustainable concepts". However, as some participants asked for additional checklist items, future work is needed to extend the current version and explore dependencies between the concepts (e.g., does a certain concept require the existence of another concept).

Concerning the next principle of alternative solutions (**DP3**), three observations emerged: first, providing alternative solutions such as in the form of taxonomies gives impulses and examples for redesigning business model elements. In Episode 6, the participants from our industry partner drew on such taxonomies and, for example, discussed how to design more ecological-friendly alternatives—discussing the replacement of on-site maintenance with remote services. Second, participants argued that they used alternatives to compare their situation on hand with additional concepts, for instance: "[...] we have to analyze whether it is better to buy from an online shop that has a center of distribution or whether it is better to drive to single stores for buying a product". The demand for comparison is further emphasized by "We need a type of sustainability leader in a certain domain to compare our solution and to identify weaknesses and strengths [...]". Even though this study's prototype provides functions for using elements from taxonomies, it does not automatically facilitate comparison with good practices. Third, against this backdrop, we could reveal that some participants (Episode 3) tend to configure their business models through the provided elements from the taxonomy, and thus, make rather unreflected decisions—which might hinder finding innovative and creative solutions.

Instead of implementing rather complex and holistic approaches for assessment (**DP4**), we made use of the trade-off analysis. During the evaluations, two major observations emerged: first, the groups who used the analysis provided by the software stated: "We were forced to discuss certain elements, which is very helpful to stay focused [...] otherwise, we

tend to improve the entire model and our discussion becomes too broad"—thus, the focus on certain elements could be increased. Second, since this feature only allows for collecting positive and negative aspects, we observed that the groups started to discuss each element quickly and that the focus on a certain element reduces the assessment's complexity. Participants from Episode 2 argued that "[...] often we did not know whether an element is good or bad, thus, we started to collect single reasons which help to get an initial evaluation later on". Nonetheless, participants also emphasized issues such as simply adding more small positive aspects and just one huge negative one may lead to a false interpretation, which has to be taken into account in future research (see also Discussion).

With regard to the last principle (**DP5**), the evaluation indicates two main points: first, considering perspectives on a business model leverages and focuses discussions on sustainability, acknowledged in Episode 2, for instance: "The layer-oriented discussion allows for collecting more positive and negative effects to a certain point of view". Second, we observed that the differentiation between three perspectives (in our prototype through tabs) may complicate the understanding of what consequences might occur from specific actions across the other perspectives. A participant argued that "[...] it is hard to follow the consequences in the classic value propositions when changing something in the social dimension". In terms of collaboration with different stakeholders, especially Episode 2—as it took about four months—discloses some insights: first, as a positive effect, we could observe an intensive use of the trade-off-analysis (here about 17 assessments), comments in the discussion board as well as invitations of co-workers and experts for evaluating new ideas. Second, in contrast, participants stated that they tended to use further tools such as messaging services wherefore design decisions were less traceable. Accordingly, the integration of existing infrastructures for communication might be helpful so that users can draw on the services they are used to.

In summary, across all episodes, we found promising indications in artificial and naturalistic settings that emphasize the applicability of the design solution for considering sustainability in business models.

Discussion

Contribution and implications

In this article, we propose prescriptions for the development of BMDTs that support sustainability-oriented reflection. Our findings complement other facets of BMDTs that, for instance, focus on collaboration (Ebel et al. 2016), replication of the sticky note experience (Fritscher and Pigneur 2010), experimentation (Haaker et al. 2017), or creativity (Voigt

et al. 2013). In attempting to achieve our goals, we derived knowledge that is evaluated through an expository instantiation in the form of a software prototype (demonstrating the utility or suitability of the artifact, Peffers et al. 2012). We focus on software support because we want to generate and evaluate a wide range of ideas and functions which might be harder to apply with paper-based versions, for example, logging discussion on design decisions, customizing underlying BMMLs, linking elements with external data/web-based documents, searching and filtering checklist items, or location-independent collaboration. Nonetheless, we believe that some of the principles presented might also be applicable for non-software supported business model development (see Appendix 1 for discussion on the applicability in digital/analog settings).

In doing this, our study's contribution is threefold: first, a web-based **software prototype** is presented, which acts as a situated implementation (Gregor and Hevner 2013). The prototype implements feature that can be applied, for example, by practitioners (i.e., business model developers, entrepreneurs) to represent and analyze business models in terms of sustainability. In providing this, we respond to recent calls for BMDT functionality to be investigated (e.g., Bouwman et al. 2020; Szopinski et al. 2019). Moreover, the BMDT functions' frequency analysis from Szopinski et al. (2019) indicated that those functions particularly relating to non-financial assessment and customization of semantics are still rare, for which reason this study's prototype provides exemplary ways of implementation. Generally, in line with characteristics of decision support systems (Dellermann et al. 2019; Morana et al. 2017), this article's functions can be differentiated into two classes for *informative guidance* and *suggestive guidance*: for informative guidance, we present functions including visualizing business models and sustainability (DF1-DF4), collecting potential impacts (DF10-DF12), and taking different views on a model (DF13-DF16); for suggestive guidance, we provide checklists that advance sustainability (DF5-DF7) and alternative solutions utilizing business model taxonomies (DF8-DF9).

Second, we extend research on business model tooling by presenting prescriptive **design knowledge** in the form of design principles and features which can be transferred into new solution spaces (Chandra et al. 2016). While this study is anchored in the context of sustainability, and thus develops knowledge for a specific class of artifacts, it opens avenues for the understanding of how a broader class of tools that need to be adapted to specific contexts might be designed. Accordingly, we argue that it is fruitful to investigate the applicability of (a subset of) the proposed principles in additional domains such as the law that due to new regulations is also essential for sustainability. In that domain several principles can be instantiated, for example: creating different views (DP5) on law such as from lawyer and laypersons (e.g.,

role-specific understanding, Curtotti et al. 2015); alternative concepts (DP3) for the specification of law (design patterns, Haapio and Hagan 2016). As another example, Kühne and Böhmman (2018) described approaches for customizing the BMC (DP1) for data-driven business models. Results from additional domains might extend or verify our design knowledge.

By comparing the prototype and abstract design knowledge with previous (research on) tooling for business models, several observations emerged: our functions share various similarities with related tooling such as implementing an underlying BMML in the form of a canvas-based approach (e.g., Ebel et al. 2016; Fritscher and Pigneur 2014; Voigt et al. 2013) and fostering collaboration through commenting (e.g., Fritscher and Pigneur 2010), discussion boards (Ebel et al. 2016), and getting feedback (Dellermann et al. 2019). Our findings shed additional light on functions which already exist and provide alternative ways for implementing them. For instance, whereas most assessment tools and decision support systems are based on financial data (Athanasopoulou and de Reuver 2018; Daas et al. 2013; Heikkilä et al. 2016), we enable qualitative data to be obtained utilizing a trade-off analysis—comparable to stress tests that are also qualitative (Haaker et al. 2017). A set of functions implemented in this study is not addressed by related tooling including, for example, the ability to take perspectives on a business model, to be oriented through checklists, and to make use of domain-specific knowledge in the form of taxonomies. Moreover, even though many research studies emphasized the need to customize the original canvas to adapt it to a certain domain (e.g., Zolnowski and Böhmman (2014) for service, Kühne and Böhmman (2018) for data-driven businesses, Joyce and Paquin (2016) for sustainable businesses), it is only supported to a limited extent by tools. We therefore implemented different customizations including adding, splitting, merging, and changing business model components. Finally, following our study's focus on sustainability, we do not consider functions for other foci such as on uncertainties (Bouwman et al. 2012), KPIs (Voigt et al. 2013; Daas et al. 2013), or value propositions (Augenstein and Fleig 2018).

Third, we contribute to the literature on **reflection**. By operationalizing reflection, we specified design principles that guide the (re-)design of tools. Generally, reflection has some overlaps with other theories relevant to the field of sustainability such as sensemaking (Seidel et al. 2013). Although sensemaking also seeks to understand the past to handle complex situations, reflection lays an emphasis on the derivation of future actions (Prilla 2014), thus aiming at combining making sense and planning future efforts. In terms of design principles, sensemaking distinguishes between '*information disclosure*' (comparable to DP1) and '*information democratization*' (comparable to DP5) (Seidel et al. 2013). In contrast, there are unique principles obtained from reflection such as asking critical questions (DP2) and taking

perspectives (*DP5*) for which reason we would argue that the present study is complementary to existing research.

Limitations and future research

Due to its exploratory nature and the fact that research into tooling for sustainability-oriented business models is at an early stage, our study is not free of limitations. One major challenge is that the way in which design knowledge is transferred into software is based on one's own decisions (Lukyanenko et al. 2015). Although we grounded our design decisions on user feedback and literature, some of the principles might be instantiated through other functions. For instance, whilst we used an informal approach to manage consequences, others might prefer more formal ones such as mathematical simulations (see Schoormann et al. 2018 for an overview of assessment strategies). As another example, despite allowing users to implement other BMMLs such as STOF, we primarily focus on the BMC that does not have its original roots in the context of sustainability and provides a static view on business models in contrast to dynamic ones (Abdelkafi and Täuscher 2016).

A second challenge deals with the selection of the underpinning theory. As mentioned in the **Method** section, the process of finding working solution components has not been linear. In line with Gregory & Muntermann (2014, p. 645), we employed different approaches such as ideation and prototyping and, furthermore, in the beginning “played” with potential theories to examine to what extent the interim results facilitate considering sustainability. In consequence, we draw on the concept of reflection because it seems promising in helping designers to face situations with value-conflicts (e.g., a balance between economic, ecological, and social concerns) as well as making use of the experiences available within a team to divide and conquer complex problems incrementally. In the evaluations, we were able to observe that those principles for laying perspectives on an object of interest or making design decisions explicit have been especially helpful. However, although we believe that reflection adds a complementary perspective to the field, the applicability of other (more dominant) theories for business models (e.g., resource-based-view and strategic management Massa et al. 2017), for designing specific principles (e.g., morphological analysis for alternative choices, Alvarez and Ritchey 2014), for sustainable transformations (e.g., sensemaking, Seidel et al. 2013), or creativity such as from ideation (Müller-Wienbergen et al. 2011) can be investigated.

Finally, our evaluation focused on gaining qualitative insights referring to the applicability and usefulness of the artifact. In doing this, we comply with general evaluation approaches such as the ‘prototyping pattern’ in which researchers “*could show that artifact design and its corresponding prototype are suitable to solve the particular business problem*” (Sonnenberg and vom Brocke 2012b, p. 81).

Nonetheless, the evaluation remains restricted to qualitative data for which reason future research can pick up on our results to verify the design solution (e.g., Blaschke et al. 2019). Therefore, researchers might specify appropriate variables to measure reflection (e.g., feedback rates through the number of words, van Woerkom and Croon 2008), derive testable propositions, and conduct experiments. Given that some of the evaluations were performed with students, we connected with business model experts and real companies whose knowledge we considered in the design (see episode E5/E6). Also, we selected students who were enrolled in Master's studies and provided lectures to ensure a basic understanding of business models and sustainability.

Furthermore, we could deduce a set of ideas concerning business model development in general during the software applications, opening avenues for future research. As a first avenue, particularly in the workshops with the industry partners, we observed several entry points depending on the purpose of innovating business models. While one company collectively discussed their business by using BMMLs, the other company had a very good understanding of what their business does, and thus argued that the representation part was not much fruitful. Hence, individual entry points should be taken into account, for instance, by exploring how the actual purpose of business model development can be identified and which specific situations require an adjustment of the process itself (see also Schneider and Spieth 2013 who raised questions about what determines the process of business model innovation). Another avenue might focus on the trade-off between creativity and guidance. We identified a tendency of un-reflected selections of elements through the help of the implemented taxonomies. Finally, since our solution presumes participation and interaction, users need to provide feedback and attend discussions. Therefore, the willingness to use a BMDT that might depend on business and user characteristics (e.g., prior knowledge, number of team members, see Szopinski et al. 2019) needs to be explored. Taking some individual answers from the industry partners into account, it is emphasized that, for example, the more experienced users were more likely to use the software independently.

Conclusions

It is probably impossible to prescribe sustainability and we cannot guarantee that using our solution ultimately leads to more sustainability in business models. Against this backdrop, previous research has provided good reasons to believe that software (and tooling in general) can promote different actions during the (re-)development of business models which might leverage a transformation towards sustainability too. To foster this, our study sheds light on the question of how to design functions for BMDTs that support reflecting sustainability in business

models. The central outcomes of this study are (1) prescriptive knowledge and (2) an expository instantiation in the form of a software prototype that assists users in reflecting on sustainability during the visualization and assessment of business models in particular. These outcomes aim to advance previous research on business models and sustainability as well as on software tooling. Investigating these phenomena is of considerable relevance to respond to the present day's challenges such as those that are related to climate change and we hope to contribute to the understanding of how to improve businesses in their quest for economic, ecological, and social sustainability.

Appendix 1

Applicability in digital/analog settings

In this study's context of business model development aiming at incorporating sustainability, we sought to address the benefits of software support in particular. Nonetheless, we believe that some of the design principles and features derived are also applicable in analog settings. In Table 3, we like to discuss the (potential) benefits from applying the principles and features in a digital environment.

Table 3 Statement of applicability in terms of digital/analog business model development

Design principles	Design features	(Potential) Benefits of using software
DP1: Provide functions for integrating sustainability-oriented semantics into business model modeling languages in order for users to represent economic, ecological, and social aspects in business models.	DF1: Selection of pre-defined BMMLs such as BMC as an underlying structure of a business model project. DF2: Adaption of BMMLs. DF3: Linking business model elements and components. DF4: Switching between 'template'-'sticky note'-modus.	DF1: BMMLs such as the business model canvas are well-accepted in analog and digital settings. DF2/DF3: Software allows flexible customizations of BMMLs since it supports freely adapting and refining available templates. For example, IT support helps to provide deep dives into certain elements (Terrenghi et al. 2017) and pre-defined customization options such as adding, dividing, linking, and renaming components (Szopinski et al. 2019). DF4: Software allows for handling different modes.
DP2: Provide functions for highlighting sustainability-oriented key questions, concepts, and strategies that enforce sustainability in order for users to compare and take potentially relevant aspects into account.	DF5: Provide checklists with strategies, key questions, concepts, and goals for sustainability. DF6: Marking of items that have been used/discussed. DF7: Highlight items that best possible fit a certain business model element/component.	DF5: The checklist feature is applicable in both settings. Software allows for searching and filtering across checklists, extending and refining checklists, as well as providing links to external/web-documents. DF6: Both settings allow for marking items. DF7: Software can implement dependencies and dynamic forms so that (only) suitable checklist items are highlighted.
DP3: Provide functions for incorporating sustainability-oriented best practices and alternative solutions in order for users to systematically get ideas and impulses for redesigning current business models.	DF8: Integrate business model taxonomies to provide domain-specific knowledge, best practices, variants, and a set of alternative solutions. DF9: Search and filter across the taxonomies as well as transfer selected characteristics to the business model.	DF8/DF9: The taxonomy feature is applicable in both settings. Software allows for searching and filtering across taxonomies to efficiently identify appropriate business model elements, as well as storing, accessing, and handling a larger repertoire/database of business model taxonomies.
DP4: Provide functions for collecting and judging sustainability-oriented impacts of a business model (element) in order for users to identify improvement needs and to plan future efforts.	DF10: Provide a trade-off analysis to collect, discuss, and weigh up possible consequences. DF11: Indicate for each business model element if there are more positive or negative aspects collected. DF12: Track and justify design decisions for each element.	DF10/DF11: Visualizing judgments such as through voting-mechanisms are already applied in both settings. Even though collecting positive and negative reasons (i.e., trade-off analysis) can be employed within analog settings, we believe that this is easier to handle digitally because of, for instance, structuring and sorting a lot of information, editing information to ensure a certain level of abstraction, spotting duplicates, getting access regardless of time and location, as well as automatically marking which side predominates. DF12: Software allows logging the history of business model elements including, for example, design decisions as well as retrieving previous states of business models and their variants.
DP5: Provide functions for specifying sustainability-relevant perspectives on business models in order for users to handle the multidimensional issue of sustainability and incorporate stakeholders' points of view.	DF13: Provide tabs with different views (e.g., economic, ecological, and social sustainability). DF14: Invite (external) users/experts. DF15: Provide a discussion board.	DF13: Differentiating between views can be employed in analog settings such as via the Triple-Layered-Canvas (Joyce and Paquin 2016). Software allows, for instance, switching between tabs and customizing views.

Table 3 (continued)

Design principles	Design features	(Potential) Benefits of using software
	DF16: Comment specific business model elements.	DF14/DF15/DF16: Software allows integrating people regardless of time and location restrictions, thus fostering collaboration and communication both synchronous and asynchronous (e.g., Ebel et al. 2016; Szopinski et al. 2019) as well as to integrate experts and stakeholder who are more difficult to include.

Appendix 2

Classification of prototype

In attempting to provide an overview of which functions are implemented through our prototype, we make use of the taxonomy of BMDTs as proposed by Szopinski et al. (2019). Figure 3 summarizes the main features. Next, we would like to highlight the characteristics that are fulfilled through the design features implemented—further features such as technical ones and providing sticky notes (elements) are also implemented to provide a working pro-

TOTYPE but are however not in the focus of this study: *customizations* to provide the flexibility of the canvasses and allow integrating sustainability-relevant semantics in the form of freely-definable business model framework components (DF1-DF4); *templates* in the form of business model taxonomies (DF8-DF9); *non-financial support* in the form of a trade-off analysis (DF10-DF12); *user and role management* in the form of user profiles, user lists, project user lists, task management, and email notifications (DF14, DF16); *discussion board* (DF15). Moreover, as possible extensions of the taxonomy, we implemented checklists (DF5-DF7) to enforce sustainability and perspectives on business models (DF13—comparable to *element filter*).

	Dimension	Characteristics						
Modeling	Customization	Add	Divide	Link	Rename	Change arrangement		
	Development	Element		Element connection		Template		
	Commenting and linking	Textual comments on element-level	Textual comments on business model-level	Graphical comments (predefined)	Graphical comments (freeform)	Link files	Link web-resources	Glossary support
	Assessment	Financial		Non-financial		Assessment status	Correctness checker	
	Navigation and filtering	Model comparison	Element filter	Phase management	Element clipboard	Link to business models	Framework support	
Collaboration	Communication	Chat		Discussion board		User list		
	Synchronization	Asynchronous modeling		Concurrent modeling		Synchronous modeling		
	User and role management	User management		Role management	Support of task sharing	Workspace awareness		
	Repository and conflict management	Version control		Local repository		Remote repository		
Technical	Architecture	Client/Server		Client only		Web-based		
	Data exchange	Export			Import			

Legend: Features implemented by our software prototype

Fig. 3 Classification of this study's prototype (taxonomy according to Szopinski et al. 2019)

Appendix 3

Design cycles

In the following section, we provide details on the first two design cycles and highlight the refinements between both cycles. Table 4 summarizes the resulting design principles and features.

In **design cycle 1**, we started with four main design principles derived from theoretical and related literature as well as implemented these principles by means of a low-fidelity prototype.

- *DP1*: To allow flexibility and integration of sustainability-relevant semantics, we specified the principle of adaptation. Therefore, we implemented several canvas-based adaptations including adding, dividing, renaming, and changing the arrangement of components.
- *DP2a*: To guide users on how to improve a business model towards more sustainability, we specified the principle of checklists. Therefore, we implemented independent lists with general items for sustainability such as fair trade, clean production, creating local jobs, using renewable resources, recycling of products, or publicly available goods (see also Schoormann et al. 2016).

- *DP2b*: As sustainability is a multidimensional issue, we specified the principle of views. Therefore, we implemented completely different canvasses, i.e. one canvas for social sustainability, one for ecological sustainability, and one for economic sustainability. Other approaches during the prototyping sessions aimed at representing the dimension in the form of colors (e.g., green elements are important for ecological issues) or icons (e.g., a person represents social sustainability).
- *DP3a*: Since there was a need for marking which business model elements need to be enhanced in terms of sustainability, we specified a principle of assessment. Therefore, we implemented ‘traffic lights’, thus coloring improvement potential in red and coloring positive elements in green.
- *DP3b*: Business model development is a collaborative endeavor for which reason we specified the principle of collaboration support. DP3b was less respected because the groups mostly worked together in person—nonetheless, commenting features and discussion sections were designed.
- *DP4*: To leverage the ideation process during business model development, we specified the principle of domain specificities. Therefore, we implemented domain-specific

Table 4 Overview of design cycle 1 and design cycle 2 (grey cells = refined/extended)

Design cycle 1		Design cycle 2	
Design principles	Design features	Design principles	Design features
DP1: Adaptation of business model modeling languages	- Adding, dividing, renaming components - Linking elements/components - Modifying the arrangement	DP1a: Selection of business model modeling language.	- Selection of business model modeling language - ‘Template’-modus to create new or own languages
DP2a: Sustainability-oriented checklists.	- Providing key concepts	DP1b: Adaptation of business model modeling languages.	- Adding, dividing, renaming components - Linking elements/components - Modifying the arrangement
DP2b: Taking of views on a business model.	- Three canvasses for economic, ecological, and social sustainability - Icons (next to elements) that represent a view/dimension.	DP2a: Sustainability-oriented key concepts and questions.	- Providing key concepts - Asking guiding questions
DP3a: Assessment of business model and its elements.	- Traffic light-metaphor for each component and element	DP2b: Taking of views on a business model.	- Providing three layers for economic, ecological, and social sustainability that can be controlled via tabs
DP3b: Collaboration support (team)	- Commenting on business models - Providing explanations for the selection of certain elements	DP3a: Assessment of business model and its elements.	- Trade-off-analysis to collect positive/negative points - History of design decisions for a specific element
DP4: Predefined/ alternative building blocks of business models.	- Building block-based modeling approaches that visualize domain-specific knowledge	DP3b: Collaboration support (team)	- Commenting on business models - Providing explanations for the selection of certain elements
		DP4: Predefined/ alternative building blocks of business models.	- Business model taxonomies that provide typical characteristics for models from a specific domain

building blocks that were known from process modeling (e.g., see process building blocks in Becker et al. 2007).

As a result of the first evaluation in which we discussed and consolidated the results with the prototyping participants ($n = 32$) and three researchers, we could derive several needs for refinement: first, the assessment (DP3a) in particular was hard to design and perform because of a potential trade-off between assessment strategies that require a lot of effort (e.g., calculating/simulating material flows) and strategies that are too unspecific and not well-grounded (e.g., traffic light-driven coloring based on personal, non-transparent opinions without information that justifies why a certain color is used for an element). Second, we learned that the principle of checklists (DP2a) was too narrow because participants argued that it would be especially helpful to ask questions about certain aspects to start reflecting/discussing them. Third, we observed that integrating different views on a business model was hard to apply in paper-based prototypes because of challenges in terms of handling more canvasses (e.g., one canvas for each sustainability dimension) or visualizing the dimension through icons/colors (e.g., different interpretations of icon's meaning).

In **design cycle 2**, we examined the lessons learned from cycle 1 and formulated three main problems, namely (1) how to design an assessment strategy that can be quickly applied and allows transparent/traceable design decisions, (2) how to design checklists and key questions that enforce reflection of business model elements against sustainability-oriented concepts, and (3) how to design functions that allow integrating and switching between several views. Moreover, we observed that the groups in cycle 1 always started with selecting an underlying BMML that, for example, acts as the starting point for applying adaptations.

Accordingly, five major refinements of the design principles and/or instantiating features were suggested:

- *DP1a*: We added the principle of an underlying modeling language that provides users predefined business model

templates (e.g., business model canvas, Osterwalder and Pigneur 2010). Also, we implemented a function for switching between ‘template modus’ (i.e., working on the underlying modeling language) and ‘sticky note-modus’ (i.e., working on the actual business model).

- *DP2a*: We renamed the principle for checklists into a principle for key concepts and questions to open this for different concepts such as key questions for sustainability, key aspects of sustainability, etc.
- *DP2b*: Since we observed that handling different views was very challenging (at least in paper-based prototypes), we revised the functions and implemented a tab-based control that allows switching between (as a standard) economic, ecological, and social sustainability. Also, these views can be adapted because (a) literature suggests considering further dimensions such as culture and (b) participants create their perspectives such as specific stakeholders.
- *DP3a*: Referring to the business model assessment, we decided—in line with the evaluation in cycle 1—to implement a strategy that is easy to apply and tracks information in terms of decisions and group-based assessment. Thus, we decided to implement a ‘trade-off analysis’ in which the users can collect positive and negative aspects for specific model elements. In doing so, they discuss and visualize elements, and might be aware of certain problems. Besides, we allow tracking reasons for (re-)designing elements in the form of an ‘element history’ so that users can retrace the evolution of certain elements (i.e., changelogs in case elements are adjusted).
- *DP4*: As the building block-based approach for providing domain-specific knowledge, was hard to implement because of several forms, icons, etc., we decided to make use of business model taxonomies. These taxonomies help to structure domains such as Carsharing businesses (Remane et al. 2016) or FinTech businesses (Gimpel et al. 2018) and thus provide an overview of common dimensions and characteristics. We implemented functions for adding new taxonomies and using

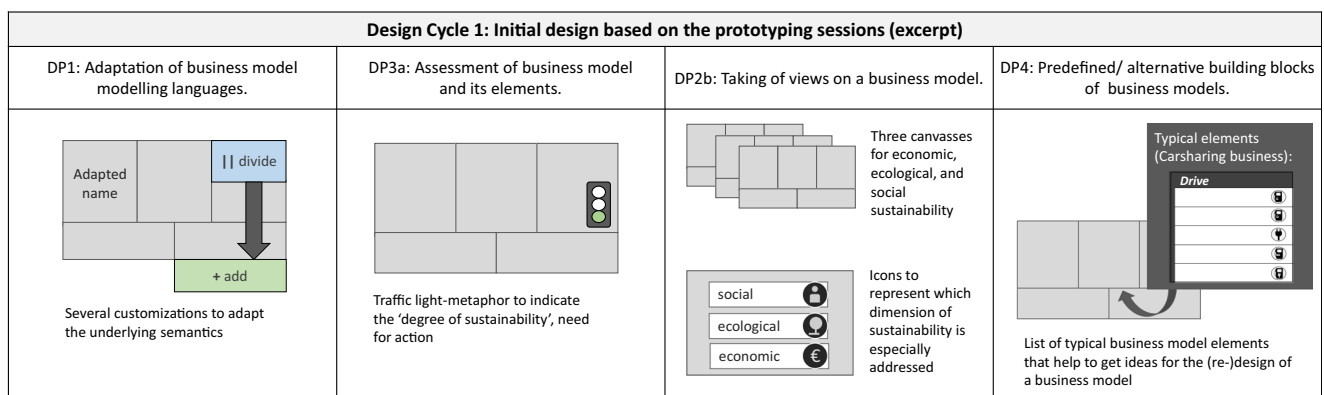


Fig. 4 Anonymized examples of low-fidelity prototypes (excerpt), during design cycle 1

taxonomies—selecting characteristics that are directly transferred into business model sticky notes.

As a result of the second evaluation in which we discussed and consolidated the results with the prototyping participants ($n = 41$) and three researchers, we could derive only minor needs for refinement: first, participants argued that it would be helpful to visualize if a business model element complies with a specific checklist item or if a team at least discussed the model’s compliance with a specific checklist item. Second, we observed that it was still challenging to decide which checklist items might be helpful for a certain design situation or business model element/component for which reason the software should guide in terms of providing a reduced set of items that can be reflected. Third, participants asked for features that represent the results of the trade-off-driven assessment in order to get impulses in which business model elements/components need improvement in terms of sustainability. Overall, participants acknowledged that the principles and features are helpful to support considering multidimensional sustainability in business models.

In **design cycle 3**, we sought to address the minor problems gained and observations that emerged from cycle 2. Thus, we suggested refinements for the following design principles and/or instantiating features:

- *DP1*: We abstracted the principles for representation (DP1a and DP1b) to a general principle for sustainability-oriented semantics that provides a visual basis of the design situation.

- *DP2*: Since there was a demand for representing if certain checklist items are already used/discussed, we implemented a checkbox next to each item so that users can mark the application of specific items. Besides, we provided initial relations between a business model component and checklist items so that users get more specific guidance
- *DP3*: As we observed that business model taxonomies are helpful to support the (re-)design of business models, we implemented features for searching across the taxonomies so that users can more easily find, select, and compare alternative business model elements.
- *DP4*: For assessment, we visualized in each sticky note (i.e., business model element) the number of positive and negative reasons collected and colored this information red (more negative reasons), green (more positive reasons), grey (equal number of reasons). In doing this, users get an initial overview of potential improvement needs.
- *DP5*: We merged principles for collaboration and views into the principle for sustainability-relevant perspectives because collaboration and communications mostly help to reflect certain perspectives (e.g., based on experiences, knowledge). To support this, we implemented features for commenting on single elements because users ask for feedback on specific parts of their business models.

As we concluded in cycle 2 that the design principles and features were helpful in its current form, we decided to implement this design solution through software (see this article’s main sections for artifact description and evaluation).

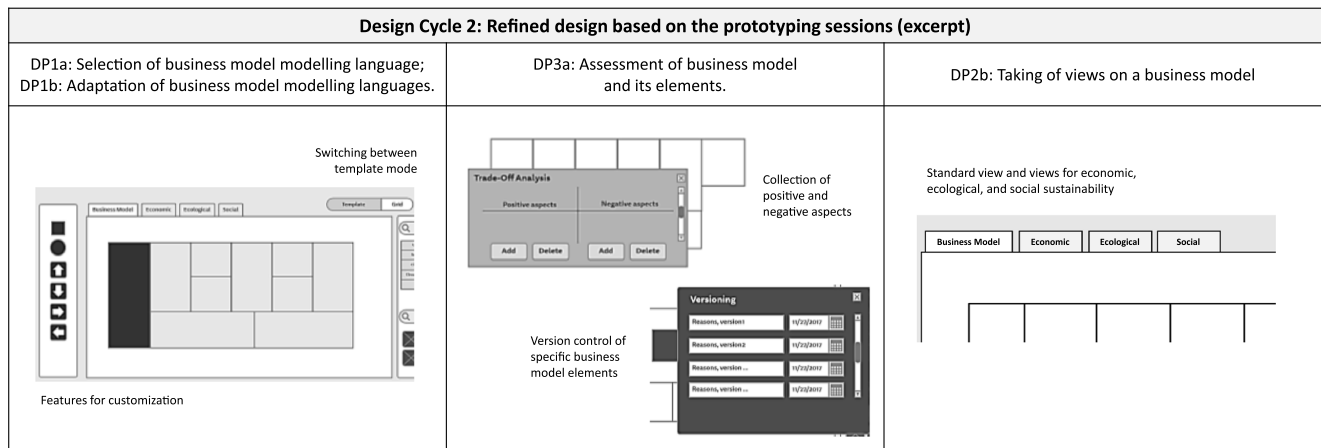


Fig. 5 Anonymized examples of low-fidelity prototypes (excerpt), during design cycle 2

Appendix 4

Evolution of design principles

In Fig. 6, we summarize the development of the design principles across the three design cycles and visualize how these principles have been refined in each cycle.

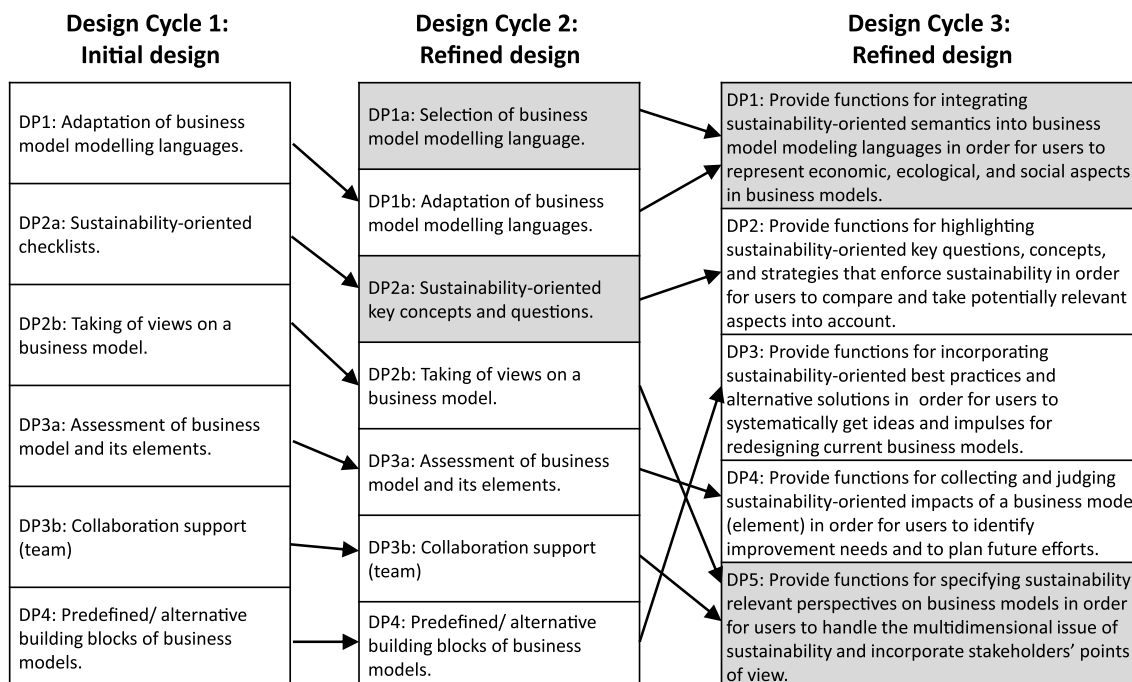


Fig. 6 Evolution of design principles

Appendix 5

Description of evaluation episodes

Table 5 Provides more details on the six ex-post evaluation episodes

Table 5 Description on evaluation episodes

Episode	Description
E1	A Design Thinking-driven workshop (about ½ day) in which five students (on a voluntary basis) from different disciplines applied, among other techniques, the software prototype to develop a sustainability-oriented business model. The workshop was held by a researcher who had not been involved in the artifact development of this study, thus acts as a user as well. In doing this, we were able to get insights and feedback regarding the application within a real workshop setting that is not held by ourselves. As part of that study, the effects on the self-efficacy of each participant were measured. Several observations emerged, for instance, (1) links between the different views were helpful to consider the dependencies between the dimensions of sustainability, (2) differentiating views helped the participants to focus their discussions and selection of elements, and (3) adapting the original canvas was helpful to visualize strengths and weaknesses of sustainability.
E2	As another episode, within a research project that deals with analyzing sustainability in business models for electrical charge-stations (for electrical vehicles in particular), a team of three researchers (two have not been a part of the artifact development) and three bachelor students enrolled in IS uses the software prototype to investigate strengths and weaknesses of current and possible future business model variants

Table 5 (continued)

	<p>in terms of sustainability. This course, with a duration of about four months, represents and reflects on existing business models as well as proposes alternative solutions, which are continuously evaluated and commented by the researchers from the disciplines of business models, service science, and electrical engineering. Thus, we were able to study the artifact over a period of time and examine how several aspects are reflected (e.g., by analyzing the texts/documents that have been created). Several observations emerged, for instance, (1) commenting functions were mostly used to communicate with external participants, (2) discussion board was mostly used to log information, (3) trade-off analysis triggered group discussions in terms of sustainability, and (4) checklists should be more highlighted.</p>
E3	<p>A group of Master's-level students reflect on a 'Green IT' business model from an industry partner and discussed the results together with the CEO of that partner to ensure the practical relevance of their findings. Therefore, five groups with 19 participants (each group with 3–4 members) of knowledgeable Master's-level students from IS, Information Management, and Environment Prevention were chosen as subjects. These randomly formed groups reflected sustainability in a real Green IT business case that addresses ecological and social aspects. In total, the workshop was divided into three major parts, each with a length of 90 min. First, to create a sufficient information basis, the sales manager of our partner introduced their business case and discussed essential components with the participants. Second and third, each group had to complete the following task: to reflect sustainability while modeling the business case presented with the software prototype. Moreover, each group created a 'changelog file' in which customization of the underlying BMML (here, business model canvas) should be described, and the application of certain software functions should be justified. To obtain additional information regarding the handling of the prototype, each group was observed by a researcher who created an 'observation logfile'. In this log file questions regarding the adaptation, procedure of modeling, use of functions, and general organization within each group had to be answered. To validate the quality and ensure the practical relevance of the resulting business model representations, an expert of the industry partner was asked to assess the correctness and completeness of the business model, the usefulness of the adaptations of the underlying BMML, and the visualization of the business model's strengths and weaknesses. Several observations emerged, for instance, (1) the trade-off analysis triggered discussions and helped to quickly identify potential for improvement, (2) perspectives allowed users to stay focus during discussions and assessments, (3) each of the five groups selected as a first step an underlying BMML, (4) four of the five groups adapted the underlying BMML, and (5) checklists provided guidance (e.g., "we are continuously motivated to reflect different sustainable concepts") but should respect to dependencies between items and certain business model components.</p>
E4	<p>Similar to Episode 3, the software was employed by four groups of 18 Master's-level students (each group from three to five participants) to visualize and reflect on a regional-based sharing business model from an industry partner (within two sessions of each 90 min) as well as to create an own sharing business model that should particularly focus on sustainability-oriented aspects (within three sessions of each 90 min). Afterward, each group presented their results and reported on the use of certain software features in terms of applicability and usefulness for the purpose of reflecting sustainability. Several observations emerged, for instance, (1) BMMLs were often adapted to create specific sustainability-relevant meanings (e.g., a participant argued that "[...] interestingly, the established canvas can be adapted like by adding new blocks for ecological and social impacts, which leverages the consideration of further aspects."), (2) general strategies for enforcing sustainability (e.g., efficiency, consistency, and sufficiency) helped to discuss business models, and (3) functions for tackling perspectives helped in tackling multi-perspective challenges of sustainability.</p>
E5	<p>In episode E5, a workshop with an industry partner was carried out to validate the applicability of the software within a real environment. In this workshop, two researchers (both involved in the artifact building) and five employees (including the CEO of the partner) have collectively employed the software prototype using a projector to visualize and reflect on the current state of their business model as well as to derive initial ideas for moving towards more sustainability in the form of different business model variants. After the workshop was held (duration: about five hours), the participants were asked to provide feedback in the form of a short questionnaire regarding the software that was employed with both open questions and closed questions by using a Likert scale from 1 low to 7 high. Several observations emerged, for instance, (1) participants predominantly had limited experience in developing business models (average: 2.5), (2) applying the software during the workshop was considered as helpful (average: 6.25), (3) the implemented key questions for considering sustainability-relevant concepts provided a good starting point for reflecting certain aspects within a group (average: 4.5), and (4) representing business model variants helped to discuss the current situation and based on that develop new ideas (e.g., a participant stated that "the visualization helps to increase the understandability of the current situation").</p>
E6	<p>Comparable to the previous episode, E6 was also performed within a naturalistic setting with an industry partner. Therefore, two researchers (one involved in the artifact building) and six employees have collectively reflected on the current business to derive ideas for the future in particular. As energy efficiency is an essential factor for the company, especially ecological sustainability was the focus of the analysis. This episode includes two workshops (each about 3 h) in which we first structure the current business model variants and afterward make use of key questions, business model patterns, and alternative business solutions to derive new variants. Several observations emerged, for instance, (1) the representation of the current business model was less important for the employees, but impulses through other examples (i.e., taxonomies and patterns) and characteristic from other business models lead to discussion and (2) collecting positive and negative impacts of the business model and its elements leveraged discussions within a team.</p>

Funding Open Access funding enabled and organized by Projekt DEAL.

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