TRACE: A Conceptual Model to Guide the Design of Educational Chatbots

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Abstract. Driven by the rising popularity of chatbots such as ChatGPT, there is a budding line of research proposing guidelines for chatbot design, both in general and specifically for digital education. Nevertheless, few researchers have focused on providing conceptual tools to frame the chatbot design process itself. In this paper, we present a model to guide the design of educational chatbots. Our model aims to structure participatory design sessions in which different stakeholders (educators, developers, and learners) collaborate in the ideation of educational chatbots. To validate our model, we conducted an illustrative study in which 25 software design students took part in a simulated participatory design session. Students were divided into eight groups, assigned the role of one of the different stakeholders, and instructed to use our model. The results of our qualitative analysis suggest that our model helped structure the design process and align the contributions of the various stakeholders.

Keywords: educational chatbots, participatory design, conceptual model

1 Introduction

Over the past decade, an increasing interest in integrating conversational agents into educational contexts has motivated the design, deployment, and evaluation of *pedagogical* conversational agents, also referred to as *educational chatbots*. Indeed, there is a wide variety of educational chatbot designs and architectures, with one review of the literature noting that "there exists as much technology used in the development of chatbots as there are educational chatbots" [16]. In light of this, a recent survey of the principles grounding the design of educational chatbots emphasized that "researchers should explore devising frameworks for designing and developing educational chatbots to guide educators to build usable and effective chatbots" [13]. Our work aims to address this gap by proposing a conceptual model that can guide the participatory design of educational chatbots. By providing the conceptual tools necessary to define the context in which an educational chatbot is deployed as well as the interaction it has with learners, our model could serve to structure participatory design sessions involving educators, developers, and learners.

2 Background and Related Work

Concerning general-purpose chatbots, Ferman Guerra identified 18 chatbot best practices, spanning user-chatbot communication, chatbot features, and human factor concerns [9]. More recently, Feine *et al.* designed a chatbot social cue configuration system "to support chatbot engineers in making justified chatbot social cue design decisions" [6]. They evaluated this configuration system with a focus group and two practitioner symposia, receiving positive feedback. In a subsequent publication, Feine *et al.* also proposed an interactive chatbot development system designed to encourage collaboration between domain experts and chatbot developers [7]. Their evaluation of an implementation of this development system through an online experiment in the context of customer service chatbots showed that this system improved subjective and objective engagement.

In education, Griol and Callejas proposed a modular architecture to integrate chatbots into multimodal applications for education, featuring the ability to easily adapt technical and pedagogical content [10]. More generally, Farah *et al.* proposed a technical blueprint for integrating task-oriented agents in education along with a proof-of-concept implementation of this blueprint [5], while Jung *et al.* proposed a set of chatbot design principles derived from a literature review of empirical studies [12].

Nevertheless, few researchers have focused on providing conceptual tools to guide the process of designing educational chatbots, including the participatory design sessions aimed at ideating these chatbots. Bahja *et al.* proposed an iterative step-by-step user-centric methodology for educational chatbots whereby learners and teachers actively collaborate during the requirements analysis, design, and validation phases [1]. Furthermore, Durall Gazulla *et al.* adopted a collaborative approach, involving students in the design of chatbots for reflection and self-regulated learning in higher education, and focusing their study on challenges encountered during the co-design process [3]. While these studies have incorporated participatory design sessions for the co-creation of educational chatbots, to the best of our knowledge, no study has proposed chatbot-oriented conceptual tools to structure these sessions. The model we propose in this paper aims to serve this purpose.

3 Design

Our model was conceived to guide educators, developers, and learners in designing task-oriented chatbots for education. The aim is to provide a conceptual tool that can serve to structure participatory design sessions in which stakeholders collaborate to design these chatbots. The model provides two guidelines. First, it proposes five components considered essential in defining a chatbot's integration into a learning activity (i.e., *Tasks*, *Resources*, *Applications*, *Cues*, and *Exchanges*). Second, it outlines a procedure for how the design process should unfold, assigning specific tasks to each of the stakeholders involved (i.e., *Educators*, *Developers*, and *Learners*).

3.1 Backdrop

The backdrop for our model's components and the process in which these components are defined is a *learning activity*. Depending on the scope of the design session, this activity can be selected in advance, chosen by all participants, by each group, or ultimately by each educator present in the session. This activity can be as general (e.g., learning to draw) or as specific (e.g., learning to draw seagulls perched on a boat) as necessary. For illustrative purposes, we will use *Learning the Python Code Style Standards* as an example of a learning activity.

3.2 Stakeholders

A wide range of stakeholders, from administrators to parents, are involved in the design and implementation of educational technologies. Nevertheless, three key actors stand out given their roles in how these technologies are developed, integrated into the classroom, and exploited. These actors are (i) the *educators* who choose which technologies to integrate into their teaching practices, (ii) the *developers* of these technologies, and (iii) the *learners* who will eventually use these technologies. In this section, we outline their role in the participatory design process structured by our model.

Educators are often the ones who select the material and technology to be used in their practices [18]. In our model, educators initiate the design process by selecting the *tasks* and *resources* that will serve to scaffold the pedagogical scenario. The selection of these two elements serves to frame the chatbot integration with learning scenarios that are relevant to an educator's practice.

Developers in education have the important role of building the technology used in practice, with research suggesting that developers benefit greatly from collaborations with educators when building educational technologies [4]. In our model, developers bridge the scenario and interaction aspects of a chatbot's integration. That is, developers are the ones in charge of designing the *applications* that will both feature the resources selected by the educator and host the chatbot that will interact with the learner.

Learners are the ones who will interact with the chatbot and, therefore, the end users of this technology. Of particular importance is that learners consider the interactions timely and engaging, all the while being relevant to the learning activity at hand. In our model, learners are the ones that will lead the process of defining the *cues* used to provide ways to trigger the chatbot interaction, as well as the content of these *exchanges* themselves.

3.3 Components

Our model—summarized in Figure 1—focuses on five components to guide the integration of chatbots into educational contexts. Indeed, the model takes its acronym (*TRACE*) from the components it defines. The first two components (*Tasks* and *Resources*) focus on the scenario in which the interaction will take place, while the last two (*Cues* and *Exchanges*) focus on the interaction itself. The central component (*Applications*) serves as a bridge between the scenario and the interaction and is responsible for hosting the chatbot. The design decisions made for each component are led by one of the stakeholders involved in the participatory design session. In this section, we present each component, describe it, and provide illustrative examples.

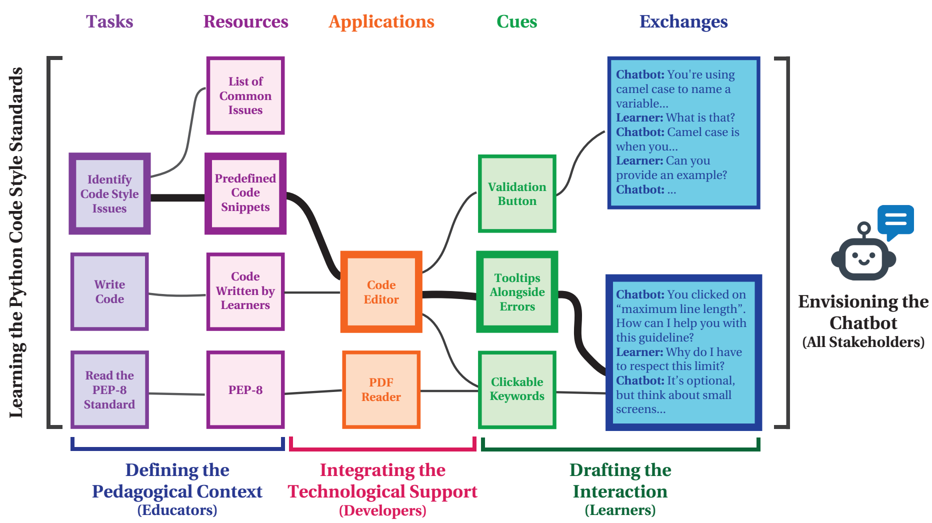

Fig. 1: Overview of the TRACE model including its components and the tasks associated with each stakeholder. The thick line represents how the stakeholders can then *trace* a line through the components they select for their design. (Chatbot icon by Vector Stall [19].)

Tasks. A task in our model can be conceived as a structured step that is aligned with the objectives of the learning activity. This is based on the idea that learning tasks are "an interface between the learners and the information offered in the learning environment" and "serve to activate and control learning processes in order to facilitate successful learning" [17]. Educators take the lead in defining the tasks that are best aligned with the learning activity. *Examples: (i) Learners have to identify code style issues in snippets of code. (ii) Learners have to write a snippet of code following the official style guide for Python code (PEP-8).*

Resources. A resource follows from the definition of a learning object as "any digital resource that can be reused to support learning" [20], but specifically applied to the learning tasks chosen for a given learning activity. Furthermore, a resource should be able to be featured in (e.g., embedded in, interfaced through) a software application that can make it accessible to both the learner and the chatbot. In that sense, resources in our model can be any of the examples provided by Wiley ("digital images or photos, live data feeds..., live or prerecorded video or audio snippets, small bits of text, animations, and smaller Web-delivered applications", as well as "entire Web pages that combine text, images, and other media or applications") [20], as long as they can be integrated into a software application compatible with an educational chatbot. *Examples: (i) Snippets of code provided by the educator. (ii) Code written by learners.*

Applications. Given that chatbots are a type of digital education technology, it is imperative that the bridge between the pedagogical scenario and the interaction with the educational chatbot be mediated by a software application. Applications can be contextualized to provide different interfaces to different stakeholders. That is, educators can access a dedicated interface where they can configure the application, select the resources that it will feature, and connect the educational chatbot that will be hosted therein. Learners can then use a different interface to access the resources selected by the educator. This learner interface also provides the affordances through which the learner will interact with the educational chatbot. Given the prevalence of web technologies in digital education, applications are often built to run in web browsers and be compatible with digital learning platforms. Nevertheless, applications can also be standalone desktop or mobile applications. Developers take the lead in designing the application that is most appropriate for the selected resource, as they have the required technical expertise. *Examples: (i) An application where learners can write, annotate, and execute code. (ii) An interactive reader featuring the Python documentation.*

Cues. To integrate the chatbot interaction into the learning activity, we rely on the notion of an *interaction cue*, often employed in educational technology [11]. Interaction cues serve to inform users of the actions they can take and to guide them toward a particular action [2]. The function of a cue in our model is to trigger an exchange between the learner and the chatbot. Cues are digital affordances that are an essential part of the application's learner interface. Cues can be graphical or textual and can be linked to actions that the learner takes, featured in elements within the resource embedded in the application, or exposed permanently in the interface. As is often the case, these cues could be paired with visual affordances (e.g., buttons, tooltips) that the learner can interact with. These cues should be featured in the resource and accessible via the application. Learners take the lead in defining the cues, as they will be the ones triggering and following these cues. *Examples: (i) A tooltip appears next to an error as the learner types. (ii) A button that the learner can click on to have the chatbot inspect the code.*

Exchanges. The final component serves to illustrate what a conversational exchange between a learner and a chatbot would look like. By providing examples of useful interactions, learners can both highlight their expectations of the interaction and indicate the design features, conversational capabilities, and social characteristics they expect the chatbot to have. This is an important aspect of the design of interactive agents and is guided by the Computers Are Social Actors (CASA) framework [14]. As such, understanding—and possibly curbing—learners' expectations of these interactions can serve to design a chatbot that is better adapted to the learning activity. Furthermore, these exchanges could be used to create longer examples that could eventually serve to prompt the language models used by the chatbots, as some of these models can improve their performance based on a few samples. Once again, learners take the lead in defining the exchanges, since they will be the ones interacting with the chatbot. *Example:*

- ***Chatbot:*** *Hey! You're using* `camelCase` *to name a variable. Did you know that you have to use* `snake_case` *for variable names?*
- ***Learner:*** *No. Why* `snake_case` *and not* `camelCase`*?*
- ***Chatbot:*** *Well,* `snake_case` *is the default for variables in Python...*

3.4 Process

The following process is one way in which the components proposed by our model can be defined by the stakeholders involved in the participatory design session. This process consists of four phases and can be integrated as the central activity of a workshop, following initial icebreakers and the selection of the learning activities that will serve as a backdrop. In this section, we describe these phases, providing sample ***questions*** that can guide the discussion among stakeholders, as well as a list of the ***outcomes*** that should be produced in each phase.

Defining the Pedagogical Scenario. In this first phase, educators take the design lead. The educator will start by proposing tasks that learners could do in relation to the selected learning activity and then listing the resources that could support these tasks. There is a many-to-many mapping between resources and tasks, as the same resource can support multiple tasks and one task can be supported by many resources. Once the tasks and resources have been mapped, the educator can choose the resources that they think will be most relevant to their practice. ***Questions:*** *(i) What tasks can support this learning activity? (ii) What resources are traditionally used for these tasks? (iii) Can these resources be delivered digitally?* ***Outcomes:*** *(i) A description of tasks that the learner could engage in. (ii) A description of resources that can be used to support these tasks. (iii) A mapping between the tasks and the resources.*

Integrating the Technological Support. The second phase concerns the technological scaffolding that will serve as a bridge between the pedagogical scenario and the interaction with the chatbot. The developer leads this phase and needs to sketch out an application that could feature the resources selected by the educator. If a resource cannot be embedded in or handled by an application, then a different resource needs to be selected. Once one or more applications have been sketched out, these applications can be mapped back to all the other resources in the list that they can potentially support. Once again, this is a many-to-many mapping. ***Questions:*** *(i) How can the selected resources be embedded into an application? (ii) What devices would this application run on? (iii) What learning platforms is this application compatible with?* ***Outcomes:*** *(i) Descriptions of applications that can feature the resources selected in the previous phase. (ii) Sketches or mockups of how the applications will feature the respective resources. (iii) A mapping between the resources and the applications.*

Drafting the Interaction. The third phase is led by the learner, who will first identify what cues within the application (or the resource embedded therein) should prompt the chatbot to start an interaction with the learner. These cues can also define where the interaction takes place within the interface. The developer needs to ensure that the cues are compatible with the application and can be displayed to learners. Once the cues are defined, the learner can choose one or more cues to construct sample exchanges between a learner and the chatbot. These exchanges do not need to be long or detailed but should contain enough information so as to envision what a dialog would look like. ***Questions:*** *(i) What elements or affordances in the resource or application can serve to cue the chatbot interaction? (ii) Are these cues specific to one (type of) resource or are they applicable to other (types of) resources? (iii) Are the exchanges aligned with the goals of the learning activity?* ***Outcomes:*** *(i) A description of one or more cues that could be present in the selected applications. (ii) One or more sample dialogs illustrating an exchange between the chatbot and the learner. (iii) A mapping between the cues and the exchanges.*

Envisioning the Chatbot. At this point in the process, stakeholders will have produced a complete mapping of all the components that could serve to support the integration of chatbots into the learning activity. In the final phase, participants use the five components defined in the previous phases to envision the chatbot. Stakeholders can then highlight the examples of each component that are most appropriate for the chatbot integration and *trace* a line from learning activity to chatbot, as shown in Figure 1. This line serves to visualize the interactions that learners will have with the chatbot, linking particular examples of exchanges with learning tasks, via the corresponding cues, applications, and resources. Once this link is established, stakeholders can define the chatbot's identity, what social cues it will be equipped with, what it will look like, and what strategies it will use to support these interactions. All stakeholders are invited to be equally active in this phase, as the chatbot's identity serves to summarize various aspects defined in the previous phases. The final outcome of this phase could be the starting point for future participatory design sessions, an initial prototype, or other iterations of this exercise. ***Questions:*** *(i) What is the chatbot's name and what does it look like? (ii) What social cues can the chatbot harness in its interactions with users? (iii) What technologies power the chatbot so that it can support the sample exchanges?* ***Outcomes:*** *(i) A description of the chatbot's identity. (ii) A list of the technologies needed to support how the chatbot interacts with learners (e.g., rule-based scripts, AI-based solutions). (iii) A sketch or mockup of the chatbot embedded in the application.*

4 Methodology

To validate our model, we first conducted two pilot studies comprising a workshop with eight researchers and developers in education and a case study with an undergraduate student completing a semester project on designing educational chatbots. We then conducted an illustrative within-subject study in which 25 students—all enrolled in a course on software design—took part in a simulated participatory design session. The purpose of these studies was to address one main research question: *Does the TRACE model help guide educators, developers, and learners in collaboratively designing educational chatbots?* Our analysis focused on two aspects of this research question: (i) alignment between stakeholders and (ii) feedback provided about our model. In this section, we present the methodology followed for our illustrative study.

4.1 Participants and Procedure

The purpose of our main study was to demonstrate the feasibility of our proposal and was conducted as an hour-long role-play activity as part of a software design course at the University of Neuchâtel, Switzerland. A total of 25 students (7 female, 18 male) were recruited as participants for the session, which took place in December 2022. At the beginning of the session, participants were divided into eight groups of three or four. These groups corresponded to groups in which the students had been working on for one of the course assignments. As such, students within each group were well acquainted with each other.

To motivate the session, after a short introduction, the groups were first asked to come up with a learning activity or choose one from a list (e.g., *how to cook pasta*, *calculating the area of a circle*). Participants were then asked to interact with a chatbot powered by the GPT-3 language model for a few minutes. The topic of this interaction was supposed to be the topic they had come up with or selected from the list. Within each group, participants were then assigned the role of *educator*, *developer*, or *learner*. They then completed two exercises. In the first exercise, participants were asked to provide a short answer describing—from the point of view of their role—how they would integrate a chatbot into the learning activity chosen by their group. After this exercise, they were introduced to our model through a short presentation. This presentation constituted the intervention in our within-subject setup.

The short presentation consisted of five slides in which the different components of the model were outlined and examples of each component were proposed. These examples specifically covered the PEP-8 use case. After the intervention, participants completed a second exercise. In this second exercise, participants were instructed to use our model to collaborate on the design of the chatbot integration. At the end of the exercise, the groups provided short descriptions of each of our model's components in the context of their respective learning activity, as well as an optional mockup of the chatbot integration. Finally, qualitative feedback was captured through an open-ended question that asked participants if they found the model useful.

4.2 Instruments and Data Analysis

We captured qualitative responses through short answers to a series of open-ended questions. In the first exercise—before the presentation of our model—participants were asked to specify how they would integrate the chatbot in a few phrases. Although they worked as a group, each student was asked to provide an answer from the point of view of the role they had been assigned. In the second exercise, participants had to specify each component of our model in a separate input box. Finally, groups were asked to provide feedback about the model.

All student responses were analyzed using line-by-line data coding. Furthermore, responses concerning the alignment aspect were tagged as either *aligned* or *misaligned* depending on whether they were compatible with other responses from the same group. Component descriptions were also tagged as *valid* or *invalid* depending on whether they were applicable to the respective component.

5 Results

In the first exercise, seven groups provided more than one answer on how they would integrate the chatbot into the chosen learning activity. Only in two of these groups were the answers provided aligned. In the second exercise—after being introduced to the TRACE model—all groups provided descriptions of each of the components of the model. For all groups, the descriptions of all components were aligned within each group. Furthermore, four groups provided valid descriptions for all five components, while two groups did so for four components, and the other two groups for only three components. To illustrate the answers provided, Figure 2 presents word clouds corresponding to each component.

Tasks Resources Applications Cues Exchanges

Fig. 2: How groups defined the different components of the TRACE model can be illustrated with word clouds to highlight important keywords.

Finally, four groups provided feedback on the usefulness of the model. Three groups responded positively, while one group described the explanation of the model as *complicated*. This last group provided the following feedback: *"It was complicated to understand what was asked and the explanation of [TRACE] was really fast so we didn't have time to understand."* Nonetheless, two groups specifically referred to the model's ability to *structure* the design, while one group appreciated how it was *inclusive* in the sense that it took input from multiple stakeholders into account: *"Creates some structure. Allows [one] to think about all points of view and not [miss] one... This framework allows therefore to take on every stakeholder."*

6 Discussion

Our current findings are promising. While preliminary, results from our illustrative study suggest that our model helped students collaborate more efficiently by aligning the contributions of the different stakeholders and providing a structure with which to reason about the educational chatbot's implementation. Aligning the expectations of different stakeholders was one of the challenges highlighted by Durall Gazulla *et al.*, who specifically noted that one obstacle they faced in the design of their chatbot was the "challenge [of] addressing diverse needs, while ensuring the relevance of the solutions envisioned" [3]. By assigning specific responsibilities to different stakeholders, but inviting them to participate in the full design process in order to align their different needs, the TRACE model could help address this challenge.

Furthermore, the fact that the model was reported to provide *structure* for the design process addresses another challenge highlighted by Durall Gazulla *et al.* [3]. Namely, the challenge of translating research into practice. One outcome of a participatory design workshop structured with the TRACE model is a diagram that can serve as a blueprint to further design and develop the educational chatbot in question. While it is not a functioning chatbot, this outcome can be shaped into a sketch, a mockup, or even a prototype. In essence, it serves as a way to translate the ideas emerging from the participatory design session into actionable tasks for the stakeholders who will implement this chatbot in practice.

However, it is important to note that one group described the model as *complicated* and that four groups did not provide valid descriptions for all components. Although misunderstandings of the TRACE model could be mitigated by allotting more time to present the model, participatory design workshops are also limited by time constraints and include stakeholders with different backgrounds and technical aptitudes [3]. Hence, long presentations featuring abstruse terminology and complex definitions should be best avoided. Instead, ensuring that component definitions are clear and accessible to a wide variety of stakeholders could be crucial to maximizing adoption in participatory design practices.

Our model could also help educators adapt their teaching practices in light of the impact large language models (e.g., ChatGPT [15]) are having on education. It has recently been highlighted that "occupations in the field of education are likely to be relatively more impacted by advances in language modeling than other occupations" [8]. The TRACE model could serve as a canvas for educators to collaborate (i) with developers to better understand the opportunities and limitations of large language models and (ii) with learners to better understand how learners envision using chatbots to support their studies.

7 Conclusion, Limitations, and Future Work

The model proposed in this paper addresses the lack of bespoke conceptual tools for structuring the participatory design of chatbots. By outlining five different components that can be defined over a four-step process, TRACE breaks down the task of specifying how chatbots can support a given learning activity, which could be interpreted differently by different stakeholders. To maximize relevance in practice, the model places educators first, allowing them to define the pedagogical scenario that will guide the design process. Developers, due to their technical expertise, are also central in our model, ensuring that the pedagogical scenario can be supported by the technology in which the chatbot will be embedded, and bridging the scenario with the interactions that will occur between the chatbot and the learner. Finally, learners are tasked with identifying both the timing and content of these interactions, ensuring that the chatbot adds value to the learning experience, rather than being an element of distraction. The result is a model that can be used to produce a blueprint of how an educational chatbot could be integrated into a learning activity. This blueprint could be the input to future participatory design sessions, guide educators in adapting their lesson plans to make room for learner-chatbot interactions, or serve as a starting point for a technical specifications document or prototype.

Nevertheless, our study has limitations worth addressing. First, while we explicitly chose students from a software design course to maximize the number of participants that could play the role of the different stakeholders, our role-playing study is not indicative of how professional educators, developers, and learners might judge our conceptual model. Conducting a formal participatory design workshop with actual stakeholders could help improve the ecological validity of our proposed tool. Second, the limited time that participants had to interact might have affected their ability to efficiently understand and harness the model. Extending the workshop to a two or three-hour session could give participants time to assimilate the concepts presented in TRACE. We aim to address these limitations in future work.

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