The French Kitchen: Task-Based Learning in an Instrumented Kitchen

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ABSTRACT
Ubiquitous computing technologies have traditionally striven to augment objects and the environment with sensing capabilities to enable them to respond appropriately to the needs of the individuals in the environment. This paper considers how such technologies might be harnessed to support language learning, and specifically Task-Based Learning (TBL). Task-Based Learning (TBL) involves doing meaningful tasks in a foreign language, emphasising the language's use in practice. TBL is seen as a highly engaging and motivating approach to learning a language, but is difficult to do in the classroom. Here, learners typically engage in activities that only simulate 'real-world' tasks, and as such only rehearse language use, rather than applying the language in practice. In this paper, we explore how an instrumented, context-aware environment whose design is grounded in pedagogical principles can support TBL. We present the French Kitchen, an instrumented kitchen for English speakers who are learning French, and describe a 46-participant evaluation of the kitchen. Based on the evaluation, we provide a set of design recommendations for those building instrumented systems for TBL.

Author Keywords
Task-based learning, instrumented environment, situated interaction, building-people interaction.

ACM Classification Keywords
H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous. K.3.1 [Computers and Education]: Computer Uses in Education – Computer-assisted instruction.

General Terms
Experimentation, Human Factors.

INTRODUCTION
Learning modern foreign languages offers rich rewards including improved cultural understanding, communication abilities and job prospects. However, in recent years the number of school pupils gaining such qualifications in the UK has decreased significantly. At the same time, the European Union has acknowledged that Europe faces specific challenges regarding increasing foreign language proficiency, an area which impacts the EU economy [5].

Computer Assisted Language Learning (CALL) is an active research area [2] and has been posited as one means by which students might better engage in language learning. CALL increases motivation and confidence by promoting autonomous learning and, arguably, letting students engage with learning via actions that closely mirror their daily activities [4]. One added benefit of CALL is that it provides a wealth of accessible examples of authentic language use via media such as blogs, social networking and Computer Mediated Communication [6] [26]. This is significant: such realistic language production materials are an important resource for students. Despite the benefits, CALL has not been used effectively in the UK and fewer people are engaging in language studies at school or later in life [13].

Task-Based Learning (TBL) has learners use a foreign language to achieve meaningful goals (in contrast to conducting language learning through textbook-based exercises). TBL is an effective approach to language learning: using language in response to real tasks supports better learning [27]. Tasks can range from getting directions to haggling for goods in a market. However, it can be difficult to support this approach, especially in formal learning environments such as classrooms, which do not lend themselves to TBL. Formal learning environments afford a specific set of tasks and behaviours, but these are generally academic in nature (learning *about* things). By contrast, TBL calls for the use of real-world skills in real-world situations. Designing systems to support TBL is difficult, illustrated by the dearth of work in this area.

We believe that ubiquitous computing technologies are an excellent tool to address this problem. By augmenting objects and the environment with sensing capabilities that enable tracking of learners' progress in given practical tasks, and by providing situated and language-related feedback, Ubicomp systems can effectively extend the learning experience by embedding it into everyday activities. Given this backdrop, we developed the French Kitchen, an instrumented kitchen to support learning a foreign language. We chose to use a kitchen because cooking lends itself to the principles of TBL. For the purposes of evaluation, we chose to equip it with materials to support English speakers learning French. Our goal was to apply the pedagogical principles and procedures of TBL outside the classroom environment, in the kitchen. We designed the kitchen to support independent, autonomous learning – that is, it is designed to be used without the presence of a teacher. The kitchen offers a way to explore how digital interactions can support TBL.

This paper makes a significant contribution to the field through identifying TBL as a novel application area for Ubicomp. We show how Ubicomp systems can be designed according to TBL pedagogy through describing the design and development of the French Kitchen, which supports English speakers learning French whilst engaging in a cooking activity. Our evaluation of the French Kitchen with a 46-participant study reveals two important design guidelines that can usefully inform the design of Ubicomp systems for TBL in the future.

UBICOMP FOR TASK-BASED LEARNING

Building digital technologies to support TBL in the wild, i.e., embedding it into everyday activities, involves a number of both technical and conceptual challenges. Our approach to these challenges is informed by existing work in Ubicomp.

A key facet of a Ubicomp system for TBL is the sensing and recognition of task related actions in the everyday environment, such that the system can respond with timely, situated and language-appropriate conversation and feedback. Monitoring of activities by the environment is a well-researched topic, and instrumented environments in general are considered standard in the Ubicomp research community. A few such "smart environments" have been designed and used for applications related to cooking activities and the kitchen. For example, the Ambient Kitchen [17] is used to promote healthier nutrition by recognizing basic food processing activities using accelerometers embedded in the utensils [19], and for situated prompting and cooking support [10]. In a similar way the Assistive Kitchen is an intelligent environment addressing activity recognition by explicitly distinguishing ingredients during cooking using sensors embedded into the utensils [11]. CounterIntelligence is an augmented reality kitchen, which can provide instructive information to the users while they are cooking [3].

In order for technology to enhance a learning interaction it is often key that the technology should almost play an invisible role, where the learner focuses on engaging with the concepts to be learnt, rather than their interactions with the technology. In the case of TBL, learners should focus on the task at hand, and to a certain extent the use and production of language, with the technology there to support them in this endeavour. Ubicomp has a rich history in developing technologies that enable novel, embedded learning interactions. Probably the most influential work on enhanced interaction techniques for learning applications in instrumented environments was the pioneering Classroom 2000 project. Novel means for data visualization and capturing were integrated into a regular college lecturing routine [1]. The project aimed at a "living educational environment", i.e., providing computational services and support for learning in the learning environment itself, which is comparable to the approach presented in this paper. Classroom 2000 focused on "providing automated tools that support the capture, integration, and access of multimedia records" [1]. As such the system was more a multimedia authoring tool rather than a tutoring system. Additional Ubicomp systems have been designed to support children to engage in storytelling and creative writing activities [9]. Here, children were equipped with PDAs and free to wander the grounds of an Elizabethan manor house. Proximity to specific locations would trigger information and exercises relating to those locations, later used by the children in creative writing exercises. Alternatively, the Ambient Wood [21] project embedded sensing and receiving technologies throughout a woodland. Such embedding of technologies enabled children to engage in social constructivist learning activities as they collected data around the woodland and formed and tested hypotheses about the various woodland habitats and dependencies. More recently, Ryokai et al [22] demonstrated use of a smartphone application to help students learn about biodiversity and sustainability issues in situ.

Supporting and promoting language learning through digital means requires —at least at some point— some form of translation support. With the advent of personal digital assistants and smartphones, applications for mobile translation and computer-assisted vocabulary learning have become very popular. However, these technologies provide 'just in time' support, rather than a language learning experience in themselves. Some prior work exists that attempted to support TBL in a digital context, yet this work has been said to be 'rather limited' [14], and is primarily situated in areas such as Computer Mediated Communication, which do not support situated language use that is related to real-life activities. The tasks provided in these contexts are artificial exercises, which learners conduct in order to learn a foreign language rather than achieve a real-world goal.

To our knowledge there is no related work applying digital technology to facilitate TBL. Very few systems exist that use sensor equipped everyday environments for language learning. Ogata and colleagues use RFID technology to provide object-specific vocabulary training [15, 16]. Whilst the environment is certainly very valuable for translation and vocabulary training support [8], it is still far away from actual TBL.

THE FRENCH KITCHEN: PEDAGOGY

Given the emphasis of the authentic task within TBL we have used the kitchen environment as a learning context since the act of cooking a meal is an authentic task with a clear goal and end product. Additionally, people learning foreign languages are often motivated by a desire to immerse themselves in a foreign culture and cuisine: cooking feeds into this motivation. There is a disadvantage in the use of cooking, which is that cooking can be harder in a foreign language due to its specialised vocabulary. (Consider, for example, terms such as 'whisking' and 'deseeding'.) The advantages of cooking for TBL outweighed this drawback.

We developed the French Kitchen – an augmented kitchen designed to provide a situated language learning experience. It uses activity recognition to monitor learners' progress through a given recipe. Based on a TBL pedagogy, instructions, reminders and other language support are given in French and, when necessary, in English. We thus transform a regular kitchen environment into a TBL tool where learning the foreign language happens naturally as the students cook. Such an understanding of learning is drawn from TBL, where learning is viewed as happening incidentally: this refers to learning "without the intent to learn, or as the learning of one thing, e.g. vocabulary, when the learner's primary objective is to do something else, e.g. to communicate" [12, pp 10.].

We can support TBL with ubiquitous technologies by using sensing technology to track learner progress and provided situated, relevant feedback. However, to do this effectively it is key to base our design upon relevant pedagogical concepts. In TBL a task is carefully designed to ensure that meaning is primary; there is a communication problem to solve; there is a relationship to comparable real-world activities; completion has priority; assessment is in terms of outcome [25]. The underlying task in the kitchen was designed according to this definition: firstly, we designed it to encourage learners to focus on meaning rather than purely language (they use the language to complete a task, rather than focusing on the language itself). Secondly, learners must draw on their language skills to achieve the task. Thirdly, the task is situated in an authentic real-world context. Fourthly, the task is goal-oriented: it is clearly-defined and has a goal. Finally, learners measure their success by goal completion.

We drew on the concepts of complexity and procedure to tailor the task and system-provided help [25]. 'Complexity' relates to the amount of available support. For example, decreasing complexity involves reducing the amount of unknown vocabulary and grammar, while to increase complexity we might use more terms and less common grammatical structures. Complexity is important, both for meeting the general language needs of a learner (who may be early, intermediate or advanced) and for providing support that is relevant to the current context (when a learner is struggling with a particular phrase, for example). 'Procedure' refers to information given about how to complete the task. This is important as learners need to understand what is required of them at the current stage of the task (a step within the recipe, for example), and also have a sense of how far they are in the overall task (e.g. the whole recipe). We wanted to be able to reduce or increase complexity, and to communicate procedure. Different pieces of functionality helped achieve these goals. The majority of these were automated (and prompted by activity recognition or time-outs), but some were user-controlled.

The task procedure was to follow a recipe to make a dish. The system led learners through this step-by-step. To convey procedure, the system provided:

- timely, automated instructions, such as "butter the baking dish"
- a user-controlled 'back' function, to let users move back a step in the recipe
- a user-controlled 'forward' function, to let users move forward a step in the recipe

The automated instructions were triggered based on the automaton state and activity recognition. At any given stage of the recipe, the system would await a combination of signals showing that the learners were engaged in the current step. For example, after an instruction to sprinkle the dish with flour and sugar, the system would wait for three things to happen before providing the next instruction: data signalling use of the flour; data signalling use of the sugar; a subsequent lack of activity (because the learners had finished using the flour and sugar). The system provided automated and user-controlled support to reduce complexity, and automated support mechanisms were triggered by timeouts, each occurring after a specific time period without user activity relevant to the current task. Mechanisms to reduce complexity were:

- automated repeats of instructions
- automated reminders: prompts about what learners should be doing, for example, "don't forget the butter"
- automated reformulation: rephrasing of instructions, for example "take a little butter, and spread it on the base of the baking dish"
- automated translations into learners' first language (in this case, English)
- user-controlled repeat
- user-controlled translation

The four automated mechanisms were provided in the above sequence, gradually providing learners with more support as time passed. That is, if a learner did not respond to a repeated instruction followed by a reminder, the system would rephrase the instruction using different French words; if the reformulation was not understood, an English translation would be given. This is an example of escalation, a way of gradually changing the level of complexity (in this instance, decreasing it).

Finally, one mechanism increased complexity: this was the automated provision of tips, French phrases about cooking technique intended to provide advanced learners with more complex language while conveying cooking-relevant information.

THE FRENCH KITCHEN: SENSING, TRACKING, PROMPTING

From a technical perspective the French Kitchen consists of three main parts: a sensing and recognition module (S&R) for tracking the learners' activities and the state of the kitchen; an inference module (INF), which deduces progress through the recipe; and a prompting and interaction system (P&I) for providing situated support related to the language learning task. Figure 1 gives an overview of the system.

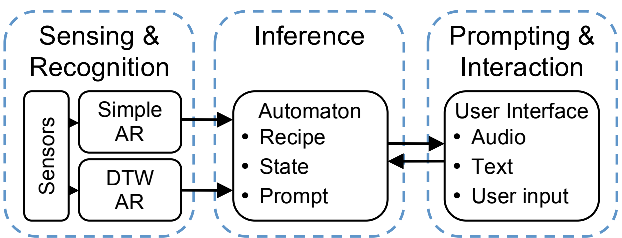

Figure 1: Technical overview of the French Kitchen

Sensing & Recognition The purpose of the S&R subsystem is to sense and recognize activities relevant to the cooking process. We did not attempt to employ cameras and computer vision for reasons of privacy and robustness. Furthermore, we ruled out body-worn sensors because they would unnecessarily encumber users and interfere with creating as natural a cooking scenario as possible. Instead, we instrumented the objects used for cooking with small, inexpensive acceleration sensors (see Figure 2). These wireless sensors are integrated into the handles of cooking utensils, incorporated into containers that hold ingredients, and directly attached to kitchen appliances (e.g., oven door, weighing scales). When a sensor detects movement it starts transmitting the raw acceleration data to a nearby receiver, which is connected to a host computer. We use Open Movement WAX3 wireless triaxial accelerometers, which are small (32×13×9mm), lightweight (5g), optimized for low-power sensing and transmission (several hours of continuous telemetry, and months in a 'wake on activity' state) and can be encapsulated in a hygienic and robust housing [18]. All sensors are configured to a sampling frequency of 50 Hz.

Two different approaches are used to recognize activities from the accelerometer data. For simple actions we employ a technique that reports motion if certain thresholds in the signal's energy and the magnitude of its power spectrum are exceeded. These thresholds have been determined empirically in cross-validation experiments. Motion events are generated if kitchen objects, e.g., food containers or the oven door, are moved. In order to recognize more complex food processing activities that are linked to utensil use, we employ a dynamic time warping approach applied to a statistical feature representation of the acceleration data [20]. By doing so we are able to recognize the most relevant basic food processing activities, e.g., stirring, slicing, chopping, scooping, with a reasonable accuracy and robustness.

Figure 2: Some of the 27 kitchen items instrumented with accelerometers

Inference In order to provide situated prompting and context sensitive interactions for the language learners, the French Kitchen needs to keep track of the progress cooks make with respect to the recipe they are cooking (INF module). The events and activities that are recognized by the S&R module are indicators for progression within the cooking task, and thus input to the recipe model. Since recipes are typically linear we focus on simple state automatons for recipe modeling that are easy to author for a human system designer. The automaton model consists of a sequence of major states – the overall task being carried out at that part of the recipe. These are associated with specific feedback actions that are used by the subsequent P&I module, examples of which are specific spoken messages, success statements and timeout statements. Each major state has a sequence of sets of one or more actions. Each set must be completed before moving to the next, but the actions within a set can be completed in any order. Each action has a condition that must be met for it to complete, for example, an activity being recognized, a fixed time delay, or a set of activities being absent for an amount of time. If an action's condition is not met within a defined interval, the next prompt for that action is read.

Prompting & Interaction Based on the definition in the automaton specifications and the inferred recipe progress, the P&I module provides language learners with situated support (cf. the pedagogy-informed design approach in the previous section) and context-sensitive interaction options. For direct interaction with the French Kitchen we use a tablet computer with a bespoke graphical user interface. This GUI guides learners through the cooking process, gives spoken prompts, and allows the users to manually request situated support. This support comprises: on-demand, on-screen transcriptions of the audible prompts or their translation to English; self-determined adjustment of progression speed by manually pausing and resuming the automaton; and manually stepping backwards and forwards to skip or repeat certain steps.

All three modules of the French Kitchen system communicate via lightweight publish-subscribe middleware; together implementing the workflow as it has been described here. All sensors are unobtrusively integrated in such a way that users of the French Kitchen are not distracted. The tablet computer is housed within a bespoke enclosure that makes it suitable for situated interaction from a kitchen work surface.

EXPERIENCING THE FRENCH KITCHEN

Two students stand in the kitchen. A recorded voice remarks: "Pour prêparer votre clafouti, vous aurez besoin des ingrêdients suivants." (To prepare clatoufi, you will need the following ingredients.) The kitchen reads aloud a list of ingredients in French, which the students jot down. Once the list is read, they fetch the items then indicate that they are ready. "Très bien"(very good) remarks the kitchen, "commençons a cuisiner" (let's get cooking).

"Préchauffez le four a deux cent déges," (pre-heat the oven to 200 degrees) says the kitchen, before falling into silence. The students are not aware of the underlying system, but while they translate and carry out the instruction, the kitchen's automaton is awaiting a signal from the oven knobs, showing that the students are on track. A timeout is counting down: if the students do not complete this subtask within a certain amount of time, the kitchen will help by giving them a prompt.

From pre-heating the oven through to coring pears and making batter, the kitchen guides the students through each step of the recipe. The students' use of kitchen items – whether oven knobs or utensils – guides the kitchen as to where they are in the recipe, and in response the kitchen gives prompts as needed, repeating or simplifying its language if initial prompts do not seem to help.

Pilot Study – Perfecting Timings

A pilot was held at a teaching kitchen in a local Further Education college. Seven sessions were conducted with pairs of learners, who were asked to make pear clafouti, a traditional baked French dessert: these were subject to audio and video recording. The system ran under dual control, with sensors running to detect activities and researchers manually providing input if needed. As well as serving as a pilot and informing practical decisions about the full evaluation, this let us understand how long cooking subtasks might take. We used this data to include realistic time-out durations in the system in the main study, e.g. indicating how long the kitchen should wait before prompting learners about buttering a dish. This is particularly important in the kitchen environment, where timeliness can be key to successful cooking, whilst also being important to support effective learning interactions.

Study – Understanding the Role of a Ubicomp System in Supporting Task-Based Learning

The evaluation took place in a purpose-built kitchen at Newcastle University. 52 participants were recruited from staff and students at the university, and placed in 26 pairs. Given TBL's focus on communication, pairing participants ensured communication occurred whilst the task was being completed. 23 sessions yielded usable data (2 participants dropped out, and the data from one pair was unusable). We asked our participants to make pear clafouti. Pairs spent 60 - 90 minutes on the task. This yielded sensor logs, audio and video recordings (which were transcribed) and responses to brief questionnaires about participant background and what they thought they'd learned in the sessions. Participants had different levels of expertise in French: since our purpose was to understand how a context-aware kitchen supports TBL, rather than to measure language acquisition in individuals, it was advantageous to see how people with different competencies responded to the environment.

We used Conversation Analysis (CA) to analyse the learning interactions within the kitchen. CA is multi-disciplinary qualitative technique used to analyse spoken interactions [23] and applied in a wide range of professional and academia areas. At its core is one question: "Why that, in that way, right now?" CA considers statements as actions (why that), expressed in linguistic forms (in that way), in a developing sequence (right now). The aim of analysing the interaction between kitchen users was to uncover the evidence of learning manifest in the details of the interaction [24]. CA is ideally suited to our task, which was to understand the ways in which the French Kitchen did or did not support learning.

A language learning and CA expert annotated the transcripts having also watched the recordings. Kitchen-learner interactions were subject to scrutiny, and considered in terms of their impact on language learning (positive, neutral or negative): each categorisation was based on two factors, whether the utterance from the kitchen contributed to learner completion of the task at hand, and whether the utterance provided the learners with an opportunity to engage with the language (e.g. discussion or repetition of a term, or execution of an instruction). This reflects the dual goals of TBL: task completion and language learning. Positive interactions might, for example, help the learners progress in the task or provide a clear opportunity for engaging with the language, while negative interactions could result in the learners expressing confusion or frustration with the system, or being unable to progress with the task. An example of a neutral interaction is a use of the translation function, which allowed learners to complete the task, but did not help them engage with language.

Interactions were further categorised according to the functionality used (e.g. user-controlled repeat, automated translate). Finally, the automated interactions were categorised according to whether they were expected – that is, we sought to mark the interactions where the kitchen behaved in an unexpected way, for example by providing untimely prompts due to inappropriate timeout durations. These annotations were subject to double coding.

RESULTS

In this section we present the frequency with which different types of interaction occurred, and four qualitative episodes showing how learners interacted with the kitchen during their cooking task and how the French Kitchen both did and did not support their learning.

Types of Interactions

Table 1 gives a count of interactions that were positive, neutral and negative, sorted by pedagogical concept and technological functionality. There are almost an equal number of interactions that resulted in a positive or negative impact on learning (145 and 138 respectively). The majority of interactions (288) were neutral.

Table 1 shows that automated reminders and translations frequently had no (or negative) impact, while automated repeats and reformulations, along with tips, met with greater success. User-controlled functions generally resulted in fewer negative impacts, a phenomenon that we revisit in the Design Implications section.

Although most pairs consisted of one beginner and one mid-to-advanced French speaker, 4 of the 23 pairs consisted of only beginners. These participants had low confidence in their English and lower confidence in their French. As shown by Table 1 (where beginner interactions are shown in brackets), their usage patterns differ starkly: particularly, these 8 participants were responsible for 112 of the 118 usages of user-controlled translation.

Pedagogical concept	**Technological feature**	**Impact on learning**		
		Positive	**Neutral**	**Negative**
Procedure	Automated instructions	37 (0)	102 (9)	40 (4)
	User-controlled forward / back	0 (0)	1 (0)	8 (7)
	Total (procedure)	**37 (0)**	**103 (9)**	**48 (11)**
Decrease complexity	Automated repeat	5 (1)	12 (8)	6 (0)
	Automated reminder	2 (0)	42 (12)	17 (3)
	Automated reformulation	24 (1)	45 (6)	11 (0)
	Automated translate	5 (0)	35 (9)	22 (4)
	User-controlled repeat	24 (16)	8 (8)	4 (4)
	User-controlled translation	18 (14)	92 (90)	8 (8)
	Total (decrease complexity)	**78 (32)**	**234 (133)**	**68 (19)**
Increase complexity	Tip	30 (5)	52 (19)	22 (9)
	Total (increase complexity)	**30 (5)**	**52 (19)**	**22 (9)**

Table 1: Count of interactions to have positive, neutral and negative impact on learning, sorted by functionality. Numbers in brackets show the subset of interactions which involved pairs of beginners (4 pairs of 23).

Learning Interactions in the Kitchen

This subsection describes four episodes that illustrate interactions with the kitchen. These episodes show how we implemented the pedagogical concepts, and the positive, neutral and negative impacts that our system had on learning. The first episode, 'peeling the pears', shows an instruction (procedure) followed by use of the 'translate' button (decreasing complexity) to positive effect. In 'ingredient list', the second episode, students struggle to keep pace with instructions (procedure), with a negative impact on learning. In 'quartering the pears', we see an instruction (procedure) followed by a reformulation (designed to decrease complexity but arguably increasing it), triggering positive learning. Finally, in 'translations' a beginner-beginner pair overuse the translate function, illustrating a neutral impact from functions that convey procedure and decrease complexity.

Table 2 describes the notation used to describe the episodes.

FK	French Kitchen
S1, S2	Student 1, Student 2 (these may be different people in different episodes)
R	Researcher
(.)	A brief pause
(3.0)	A pause of 3.0 seconds
[speech]	Overlapping speech
{speech}	An addition on the transcript translating speech into English
(activity)	Describes a physical activity

Table 2: Transcription Notation

Episode 1, Peeling the Pears: Procedure, Decrease Complexity, Positive Impact

	Speaker	Utterance / activity
1	FK	épluchez les poires {peel the pears}
2	S1	I don't know what that means
3		(an aside, where they count pears)
4	S1	right tell me again lady (2.9) how do I make her [tell me]
5	FK	[n'oubliez pas] d'éplucher les poires {remember to peel the pears}
6	S1	éplucher les poires i'm not sure what that means (1.9)
7		(a student uses the translate button)
8	FK	don't forget to peel [the pears]
9	S1	aaaaah peel

Table 3: Episode 1

This episode opens with an utterance conveying procedure, an instruction from the kitchen asking the students to 'éplucher les poires' (peel the pears). S1 does not understand the word éplucher (line 2), and addresses the kitchen directly in line 4 as she tries to work out how to elicit a repeat. In line 5 a timeout triggers a reminder, designed to decrease complexity: we can see in line 6 that S1 still doesn't understand the troublesome word. At line 7, S1 requests a translation, and in line 9, we see the problem is resolved. This episode demonstrates instructions (conveying procedure) followed by both automated and user-controlled mechanisms to decrease complexity. The mechanisms for decreasing complexity (reminder, translation) are both appropriate: the reminder was well-timed (occurring at a point when the students have had time to reflect upon the utterance, and have realized they need further support), while S1 used the translation button effectively to identify the problematic word.

Episode 2, Ingredient List: Procedure, Negative Impact

	Speaker	Utterance / activity
1	FK	quatre-vingt-dixi grammes (.) de sucre {90 grams sugar}
2	S1	quatre-vingt-dix {90}
3	FK	cinq oeufs (.) deux cent-cinquante mili-litres de lait {5 eggs, 250ml milk}
4	S2	wow (.) slow down
5	S1	lait oh milk
6	FK	quatre poires {four pears}
7	S2	slow down! (laughs)

Table 4: Episode 2

In contrast to episode 1, which demonstrated well-timed reminders, this episode shows poorly-timed utterances from the kitchen. Here, the kitchen is listing ingredients for the learners to collect before beginning cooking (conveying procedure): however, they struggle to keep up with its pace. This episode illustrates the importance of timeliness. The fast pace of the instructions has a negative impact on the students' learning. Firstly, the pace means that the students are unable to understand the instructions. Secondly, the students are left off-balance (note the laughter in line 7): the system is so clearly not supporting them, that they are unlikely to feel comfortable working with the system or to trust that future instructions and prompts will be appropriate.

Episode 3, Quartering the Pears: Procedure, Decrease/Increase Complexity, Positive Impact.

	Speaker	Utterance / activity
1	FK	coupez les poires en quartiers {cut the pears into quarters}
2	S1, S2	(the students discuss another matter)
3	FK	coupez les poires en quatre morceaux de taille egale {cut the pears into four pieces of equal size}
4	S1	did you get that?
5	S2	I didn't really get the bottom
6	S1	it's another way of saying
7	S2	cut the (.) didn't it say something about les gar?
8	S1	coupez les poires en quatre morceaux {cut the pears into four pieces}
9	S2	cut the pears into quarters quickly
10	S1	no, quatre morceaux {four pieces}
11	S2	four [pieces]
12	S1	[four] pieces (2.0) taille {size} (.) equal size (1.5) another way of saying cut them into quarters

Table 5: Episode 3

Here, instructions are given in line 1, and prompted by a timeout, reformulated (reworded) in line 3. In this case the students are already conducting the action at the time of the reformulation. In lines 4 to 12, we see S1 explaining to S2 the rewording of the original instruction.

Reformulation was intended to decrease complexity by simplifying previous instructions. Arguably this particular reformulation increased complexity, by introducing more complex vocabulary. We see a positive learning outcome in this episode – S2 is able to piece together an understanding of line 3's reformulation - which is clearly driven by S1 helping S2 understand the reformulation.

Episode 4, Translations: Procedure, Decrease Complexity, Neutral Impact

	Speaker	Utterance / activity
1	FK	une pincée de sel
2	S1	une pincée
3		(a student uses the translate button)
4	FK	a pinch of salt
5	S1	a pinch of salt (.) a pinch of salt (1.3)
6	FK	et (.) une noisette de beurre (3.0)
7		(a student uses the translate button)
8	FK	a knob of butter

Table 6: Episode 4

Here we see a beginner-beginner pair repeatedly using the translate button (decreasing complexity) without attempting to translate the ingredients themselves. This contrasts with Episode 1, in which a learner used the translate function to understand a specific phrase having spent time attempting to translate the phrase herself. As can be seen, different learners use the same items of functionality in very different ways. We hypothesise that the students in this episode would have used the translate button differently had one or both of them been a mid- or advanced-level French learner.

We can see positive, neutral and negative learning experiences in the above set of episodes. Episodes 1 and 3 show positive experiences: in episode 1, a timely repeat and use of the translate button solves a problem, and in episode 3 a mistimed reminder triggers a discussion about language. Episodes 2 and 4 show neutral and negative interactions. In episode 2 the students struggle to keep up with the kitchen's pace as it lists ingredients. In episode 4, students do not engage with language learning, and simply translate all instructions.

Many of the negative experiences were rooted in poorly-timed utterances from the kitchen. For example, in another exchange that we observed, the kitchen reminded students "n'oubliez pas le beurre" (don't forget the butter) while they were already using the butter: one of the students responded, annoyed and reverting to English, "that's what I'm doing!"

The above episodes did not demonstrate neutral interactions: the majority of such interactions consisted of students ignoring utterances from the kitchen, generally while they were absorbed in cooking or conversation.

DESIGN IMPLICATIONS

In TBL, learners concentrate on completing an authentic task while they use, almost as a by-product, existing and new language knowledge. As such, progress through the task is integral to students engaging in meaningful use of the target language. We have so far presented an instance of a Ubicomp system, the French Kitchen, designed to support TBL. Reflecting on our evaluation of the French Kitchen and our experiences of learners working with the French Kitchen we now draw out two design lessons for building Ubicomp systems that seek to support TBL.

Share Control between the Learner and the System

All of the episodes described in this paper have shown the variety of ways that learners experienced the French Kitchen as supporting (or not) their progression through the task of making a pear clafouti. In general the data presented in Table 1 shows that many of the designed automated interactions produced by the French Kitchen had a predominantly neutral to negative impact on learning interactions. For example, the automated reminders that were intended to reduce the complexity of the instruction and task generally failed to be useful to our learners. Of 61 reminders, only 2 resulted in positive learning, while the rest distracted or annoyed students (e.g. the "don't forget the butter" interaction). The negative impact of automated translations is also noteworthy: 22 of 62 automated translations were analysed to have resulted in a negative impact on learning interactions. In contrast, user-controlled functions for decreasing complexity were generally more successful (in total 42 positive and 12 negative interactions).

It is perhaps surprising that something as simple as a reminder of an instruction might have such a negative impact on learners' interactions with and around the kitchen. However, closer inspection of these interactions suggests that it was the timing of these interactions that was most commonly problematic. For example, in Episode 2 we see the system instruct learners in a way that is not timely. As a result, their flow is broken: they lose track of the task at hand and revert to English.

We found that the kitchen often intervened at inappropriate times even though the team took great care to acquire realistic data about how long subtasks within a given recipe would take. Our experiences suggest that although it is important to time interactions well using pilot data, achieving the timeliness that makes interactions with a Ubicomp system feel seamless is difficult, especially when data about user activities is limited. It is only possible for a Ubicomp system to model an unfolding, real-time situation to a certain level of accuracy (indeed, drawing on additional technologies such as voice recognition and computer vision would not solve every problem). Our instrumented kitchen could clearly be improved in this area, but at the same time no instrumented environment can guarantee correctness all of the time.

As a result, we posit that providing learners with greater control over when and how the French Kitchen supports them in progressing through the task may be beneficial.

Instead of the Ubicomp system entirely controlling when a learner receives support in the task, or is ready for the next instruction, the system should instead offer learners choice over when and how they wish to receive this support. Such a change to the interaction design around cooking and language learning in the kitchen would result in fewer occasions when the kitchen intervenes in the ongoing activity at a time where it is inappropriate or unnecessary (as in Episode 2), which often caused frustration or confusion in our learners.

There are of course interesting pedagogical tensions around this design choice, one of which is highlighted in Episode 4. Here we see beginner learners repeatedly use the translate option to complete the task, rather than attempting to practice and use existing or new language knowledge. In essence, these learners chose to focus solely on the task-related goal, rather than the language learning goals of the exercise. As a result, we suggest that whilst a Ubicomp system may forego some control to the learner, this must be balanced with some system-control in order, in this instance, to ensure that some language use and practice occurs throughout the task. For example, we imagine a system where the French Kitchen provides a count down to when the next intervention will be *made available* rather than simply *provided*. This would result in the learners themselves having to select through an interaction with the kitchen whether they would like to receive this help or instruction, or continue without further guidance from the system. It also ensures that learners spend some time engaging with the language before receiving help from the system.

Increase Transparency of the Contextual Model

One traditional problem with systems that attempt context-awareness is the negative implications that this can have on an interaction when the system's contextual model no longer matches the user or learner's view of the world. The French Kitchen uses a simple and robust sensing system both to reason about the learners' progress through the task of preparing and cooking a clafouti, and also the learners' language abilities. Specific features were put into place to allow learners to reconfigure the system's contextual model if it did happen to misalign with what was actually happening in the kitchen. For example, the forward and back buttons were intended to let learners navigate through the recipe, and correct the kitchen if its model became incorrect. As can be seen in Table 1, the majority of these usages were negative, with learners typically being surprised by what element of the task they were returned to.

Based on learners' use of instrumented items within the French Kitchen the system makes decisions about the learners' progression through the task as well as about their language learning needs. This strategy for understanding learners' combined needs (both task and language based) sometimes led to confusion or irritation in our learners. At times the kitchen would attempt to help a learner understand an instruction, when they actually required help completing the task at hand. For example, one learner understood that the French instruction had asked her to deseed the vanilla pod, but didn't know that vanilla pods have seeds, let alone how to remove them.

In response to both of these issues, we propose introducing a mechanism that makes the system's contextual model transparent for the learner. Such transparency is reminiscent of Open Learner Modelling strategies adopted within Intelligent Tutoring Systems [7]: here, tutoring systems make available to learners the system's current model of the learners' cognitive or affective state, to encourage negotiation and understanding between learner and system. Given TBL's focus on task completion, enabling learners to reason explicitly about where in the procedure they are would allow them to monitor their own progress towards their goal. In addition, we propose that enabling learners to interact with a transparent contextual model would make it easier for them to correct the model when necessary. Finally, increasing the transparency of the contextual model may also enable learners to directly negotiate with the system regarding the kind of support they desire: help with understanding the language, or help with understanding the task.

CONCLUSIONS

We have presented the French Kitchen, an instrumented environment designed to support TBL by supporting native English speakers learning French as they cook. After a pilot study in a local college, we conducted a 46-participant evaluation at our university, to explore how such context-aware environments can support task-based learning. Towards this end, we evaluated the system in terms of the pedagogically-grounded functions it provided. This has yielded two design lessons for building ubiquitous systems to support TBL: providing learner control and increasing the transparency of the Ubicomp system. We are currently rebuilding the kitchen, accounting for these two key lessons and intend to evaluate the next iteration of the system in the light of these findings.

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