Computer-Aided Scaffolding in Communicative Language Teaching Environments

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Abstract

Educators in communicative language teaching (CLT) environments must provide scaffolding to help students process language that is beyond their competence (Nunan, 2004). Difficulty in providing such scaffolding by computer is one reason that most teacher-less mobile-assisted language learning applications are not oriented towards communicative competence. We created a language production tool that helped learners represent meaning through picture maps that encode words, word attributes, and the thematic relations between them, following Universal Networking Language (UNL) (Uchida, Zhu, & Della Santa, 2006). The tool then transformed these maps into grammatically accurate sentences in the target language. The overall effect of the transformation was to convert semantically-encoded meaning into grammatically correct phonetic form, and thus serve as a scaffold for learners to create intelligible sentences in the target language. When the tool was tested in a CLT environment, we observed that the tool provided effective scaffolding even in the absence of a human teacher.

Keywords: Communicative Language Teaching, Task-Based Language Teaching, Scaffolding, Universal Networking Language, Computer-Assisted Language Learning

Introduction

Communicative Language Teaching (CLT) is a language teaching methodology that prioritizes the development of communicative competence by providing students with communication opportunities in authentic social contexts (Canale & Swain, 1980). In classrooms that adopt CLT, teachers use a variety of tools and methods to provide these opportunities, and to facilitate learning within those opportunities. These methods include task-based language teaching (TBLT), the use of role-play, activities in pairs or small groups, discovery-oriented learning, and content-based immersion. Learners in CLT classrooms achieve higher levels of fluency and comprehensibility in the target language, as well as a greater quantity of communication in unrehearsed environments without any decrease in their performance in discrete tests of grammatical competence.

CLT is of particular interest because of a surge in mobile-assisted language learning (MALL). Increasing numbers of students are learning languages through mobile devices, and studies have shown that these learners have greater agency and autonomy, as well as the ability to define their own learning environments without constraints of location or time (Kukulska-Hulme, 2012). Nonetheless, a study of the fifty most popular computer-aided language learning applications for mobile phones found that the majority of them taught vocabulary in isolated units; were only minimally personalized to a specific learner's skills; and rarely offered feedback and explanation to correct users' errors. The authors concluded that "despite advances in language teaching that have stressed on the importance of communicative competence in language learning, MALL technology is still primarily utilized for vocabulary instruction rather than fluency building" (Heil, Wu, Lee, & Schmidt, 2016, p. 43).

There is a need to investigate ways to harmonize the methods of CLT with the possibilities offered by MALL. These trends have led to the investigation of digitally-supported CLT, or DSCLT (Dooley, 2015). Technology environments that facilitate DSCLT have the potential to achieve high levels of learner autonomy, while creating a "virtual" classroom environment (Schwienhorst, 2008). Why, then, do so few popular MALL technologies incorporate DSCLT methods?

A fundamental difficulty in implementing CLT methods in MALL is that the teacher plays a critical part in achieving successful CLT outcomes, by assuming the role of a facilitator and monitor (Richards & Rodgers, 2014). Providing access to a human instructor limits the scale that MALL applications can achieve. While some roles that a teacher plays in CLT (such as Needs Analyst) are achievable through technology, our focus is on one specific role that is more difficult to automate: the role of a teacher as a provider of scaffolding.

Research indicates that tasks in a CLT environment support language acquisition only if they adhere to a set of constraints: they must motivate learners, they must be sufficiently complex, they must support the learning process, they must feature problem-solving in interactive scenarios, and they must sequence the task process to balance language demand and language support (Müller-Hartmann & Schocker-v. Ditfurth, 2011). This balance of demand and support – in other words, the balance between independence and learning – is achieved through scaffolding (Nunan, 2004). Scaffolding is provided for language learners, who are not yet able to produce sufficiently complex language for effective communication in the classroom. Nunan states that the "art" of task-based language teaching is knowing when to remove the scaffolding; removed prematurely, the learning process collapses; maintained too long, the learner will not develop independence required for autonomous language use. There is thus a high level of dependency on the teacher's ability to modulate scaffolding to achieve just the right effect. A study on task-based instruction in online language courses examined the extent to which the teacher's scaffolding supported students, and concluded that "teacher intervention allows students to master targeted skills and gain independence; and that effective scaffolding on focus on form allows students to develop their interlanguage" (Lee, 2016, p. 94).

A review of mobile collaborative learning studies published in 2012 to 2016 (Kukulska-Hulme & Viberg, 2018) found several studies applying MALL to CLT. A representative sample is as follows. An audio-description application called Video for Speaking was described (Moreno & Vermeulen, 2015), in which participants recorded short audio descriptions of scenes from movies and shared them with coaches. Another study (Hoven & Palalas, 2013) discussed a tool called Mobile-Enabled Language Learning Eco-System (MELLES), which encompassed eight English-learning audio tasks performed by students in an ecosystem that included experts and teachers. The tasks were integrated into regular face-to-face courses. A study of a Chinese-language learning model called MyCLOUD (Wong, Chai, Aw, & King, 2015) examined a system of online peer learning meshed with in-class learning and consolidation. A study in Nigeria (Ogunduyile, 2013) examined the use of the mobile application 2go, for teachers to send comprehension and pronunciation exercises to students, and for students to send answers back to the teacher for correction. A study in Taiwan (Lin, 2014) looked at a mobile-based Extensive Reading Program featuring reading in-class reading and outside class hours, using a mobile phone.

All the aforementioned studies demonstrated successful use of MALL in CLT environments, but all of them featured teacher intervention for scaffolding and error correction. Our investigations centered around whether this scaffolding could instead be provided by a computer, and if so, to build computational tools to scaffold beginner learners in a teacher-less mobile-assisted CLT classroom.

The Nature of Scaffolding

Scaffolding is not unique to language learning: the metaphor of the scaffold was first introduced (Wood, Bruner, & Ross, 1976) to analyze the role of tutoring in problem solving. Wood et al. used the term 'scaffolding' to refer to a teacher controlling those elements of a task that are initially beyond the competence of a learner. The purpose of scaffolding is to allow the learner to concentrate on those elements of the task that are within their competence, and thus create a zone of proximal development (ZPD) in which learning can take place. In the ZPD, learning happens without conscious awareness (Vygotsky, 1978), and is facilitated by a teacher who serves as a bridge to conscious control until the learner has acquired the ability to do so themselves (Bruner, 1985).

Scaffolding requires the teacher to provide guidance and support, which is increased or decreased in response to the developing competence of the learner (Mercer, 1995). The teacher therefore has the responsibility to initially assist the learner, and then gradually withdraws this assistance as the learner assumes responsibility of performing the task (Bruner, 1985). The teacher's *responsiveness* to the learner's needs is crucial to achieving effective scaffolding (Scott, 1997). Scott posited that responsiveness has three elements: monitoring, analyzing and assisting. The teacher monitors the learner's present state of knowledge, as evidenced by their performance of various learning-related tasks. The teacher analyzes the data collected during the monitoring process, to infer the difference between the present state and the desired state of performance. The teacher then assists the student to progress from the present state to the desired state, by providing guidance. This guidance is gradually reduced and the responsibility handed over to the learner.

Technology Supports for Scaffolding in DSCLT

In a teacher-less DSCLT environment, tasks are, by definition, acts of communication that take place between two learners, or between the learner and a computer. The learner has a certain current level of competence to perform the communication act autonomously, which is a composite of the learner's vocabulary, grammar, communicative, and strategic competence. The amount of assistance provided is modulated based on the MALL technology's measurement of learner activity, and subsequent inference of the learner's level of competence.

Scaffolding a learner in a MALL DSCLT environment, therefore, requires the development of two modules:

1. The *language assistive module*, which provides assistance to a learner, at a desired level of guidance, to perform computer-mediated communication; and
2. The *adaptive control module*, which combines the roles of measurement and analysis to estimate and control the level of assistance to be provided by the language assistive module.
3. The language assistive module facilitates support, and the adaptive controller facilitates modulation of demand and autonomy. These two technologies together would be able to provide adaptive scaffolding to a language learner.

Design of the Scaffolding Tool

Background Work: Machine Translation as Scaffolding

As a baseline, we used machine translation (specifically, Google Translate) as a scaffold. Learners of French were provided with a computer-mediated communication (CMC) environment in which Google Translate was embedded in the form of a special-purpose keyboard tool. The learners were given communication tasks in pairs, and they were encouraged to use the translator as a means of scaffolding expressive and receptive communication. An adaptive controller faded out access to the translator as learners progressed in competence.

The use of this tool did not result in enhanced learning outcomes, and the learners did not feel that the tool was an effective scaffold, even though the quality of English/French translation was acceptable. On further analysis, we found that this failure of the translator as an effective scaffold could be theoretically accounted for as follows:

1. The translator did not provide *comprehensible input* (Krashen, 1981). While the output sentence in totality is comprehensible in meaning to the learner (being the translation of a sentence that they entered), the sub-components, in terms of words and word sequences, were incomprehensible.
2. The translator did not facilitate *reflection*. It has been proposed that, along with learner involvement and target language use, learner reflection is a fundamental principle for developing language proficiency (Little, 2007). While the adaptive controller facilitated some reflection in vocabulary acquisition, there was very little reflection of grammar and structure.

We then decided to explore an alternate method of scaffolding that addressed these two points.

FreeSpeech: A Generative Grammar Based Scaffolding Tool

We developed a scaffolding tool in the form of an iPad software application called FreeSpeech (U.S. Patent No. 8,712,780, 2014). The FreeSpeech tool was designed to facilitate language learners to build up a sentence in the target gradually (instead of all at once), using a semantic interlingua to aid the construction of the sentence, and therefore comprehend and reflect upon the way language structure works in the target language.

Universal networking language. Motivation for the development of FreeSpeech came from the Universal Networking Language (UNL), an artificial language in the form of a semantic network to express and exchange information (Uchida, Zhu, & Della Santa, 2006). UNL consists of Universal Words (UWs) that constitute the lexicon of UNL; *attributes* of these words and *relations* between them that constitute the syntax of UNL; and a UNL Knowledge Base that constitutes the semantics of UNL.

Universal words in UNL uniquely represented word senses of root words across multiple languages. For example, a word like *eat* may be assigned a number 2018861134 (in all languages). *Attributes* of UWs encoded word variations like tense, aspect, number and gender. For example, *2018861134.@past.@habitual* represented the habitual aspect of the past tense of the word *eat*. The expression *00.@1.@singular* represented the first-person singular pronoun *I*. *Relations* between two UWs encoded the thematic relation between them. A standard set of relations have been enumerated in UNL, for example agent (with the contraction agt), object (obj) and possessor (pos). Each such relation joins two UWs directionally. For example, the relation *agt(2018861134.@past, 00.@1.@singular)* represents that the word *I* is the agent of the word *ate* in this sentence

A sentence expressed in UNL is therefore a graph of relations between nodes, with each node consisting of a UW and its attributes.

Automatic generation of natural language. A graph expressed in UNL can be converted into a grammatically correct sentence in a specific target language (such as English or Chinese). This operation is called *deconversion*.

The operation of deconversion is possible with various algorithms based on the principles of natural language. Several deconverter implementations are described in the literature, including Russian, French, Arabic, Nepali, Hindi and Tamil (Cardeñosa, Gelbukh, & Tovar, 2005). A typical deconverter parses UNL, reconstructs the UNL graph, selects lexemes, identifies Cases and morphological features, inserts function words, and plans syntax in the generated output (Singh, Dalal, Vachhani, Bhattacharyya, & Damani, 2007).

The FreeSpeech tool. Analogous to UNL, the FreeSpeech tool captured sentence semantics through a graph of relationships between words in a sentence. The user interface of FreeSpeech used appropriate WH question-answer pairs to establish thematic relationships in the place of UNL contractions. For example, in the sentence *I want water*, the word *I* is the agent of the word *want*, and the word *water* is its object. FreeSpeech represented the former relation as the pair *Who wants? – I want*, and the latter as *What do I want? – I want water.*

FreeSpeech used pictures as a way to represent words. For beginner communicators, we believed that pictures provide a language-independent representation mechanism for words; this decision was motivated in part by the successful use of picture communication in language learning environments for children with language-related disabilities such as autism (Bondy & Frost, 1994). An initial database of approximately 2,000 picture-words were created to seed the FreeSpeech lexicon.
Both FreeSpeech and UNL could be used to create complex sentences, including ones with pronouns, cyclical relations, and multiple tenses. However, many attributes and relations in UNL were omitted or simplified when used in FreeSpeech, and provided with pictorial equivalents, for ease of use and implementation.

The FreeSpeech representation of the sentence *Her parents didn't want to see you today* is shown in Figure 1. This sentence contains the following 6 picture-words: *she*, *parent*, *want*, *see*, *you*, *today*. The picture-word *parent* has the attribute PLURAL to represent *parents*. The picture-word *want* has the attributes PAST and NOT, representing *didn't want.*

The sentence has the following relations:

> **Whose** parents? – **her** parents [Possessor]
> **Who** didn't want? – **her parents** didn't want [Agent]
> **What** didn't her parents want? – Her parents didn't want **to see** [Object]
> **Who** didn't her parents want to see? – Her parents didn't want to see **you** [Agent]

When didn't her parents want to see you? – Her parents didn't want to see you **today** [Time]

This combination of picture-words, relations and filters together are depicted pictorially as shown in Figure 1.

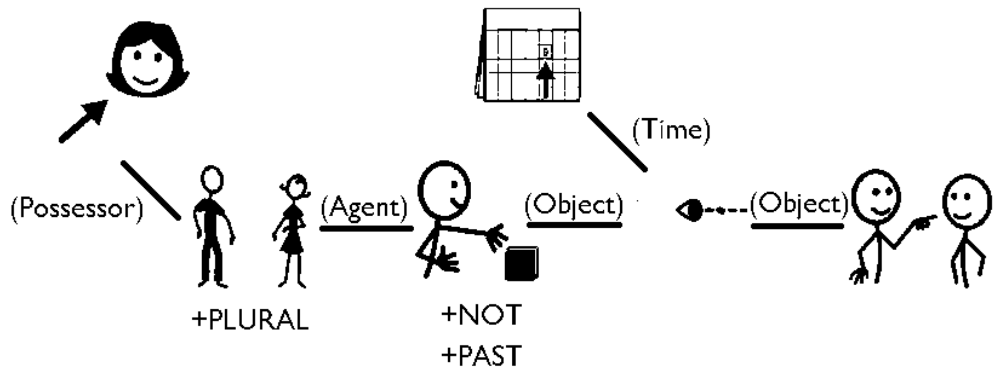

Figure 1. FreeSpeech Sentence. This figure illustrates the sentence "Her parents didn't want to see you today" constructed in FreeSpeech. Symbols are copyright n2y LLC.

How learners constructed sentences in FreeSpeech. Users of FreeSpeech constructed sentences pictorially and incrementally. The process of creating a sentence was for the learner to first find one word in the sentence from a set of pictures, and drag it to the arena. The word on the arena would then be surrounded by placeholders, each representing a FreeSpeech relation, each of which roughly coincides with a thematic relation (e.g. Agent, Object, Possessor) and represented by their respective questions (respectively, *who*, *what* and *whom* in this context). The learner then found a second word in the picture set and dropped it into a particular placeholder. This would further trigger the creation of more placeholders, around the newly dropped word. The learner would be able to manipulate attributes of the words on the arena. This process would be repeated until the entire sentence was constructed in FreeSpeech.

At each stage in the sentence construction process, the partial sentence constructed by the learner was converted into a grammatically correct sentence in the target language, and then into synthesized speech (U.S. Patent No. 8,712,780, 2014). Thus, the learner received an auditory and orthographic errorless model of the partial or full sentence, at every stage in its construction.

FreeSpeech as a scaffolding system. The end result of FreeSpeech was that a learner was able to build up a sentence using icons or images, and this was sequentially translated into the target language. This served as a means to scaffold the generation of language by the learner. Conversely, when a learner received a sentence in the target language, he was able to convert it into a network of icons or images and decipher it.

The accuracy of the FreeSpeech generative engine in producing correct forms was verified against a corpus of 7,245 sentences. The engine was able to generate 7,112 of them.

Adaptive control of the generative engine. For a learner with absolutely no knowledge of the target language, the generative engine provided a complete scaffold, so that the user could produce an entire sentence through the action of the computer alone, while providing an opportunity for learner reflection.

The computer maintained internal state for the learner's interaction with each of the learning elements of the target language, and tried to predict whether the learner had learnt each of these elements or not. The computer program gradually faded away the operation of learning elements which it believed the user had learnt, so that the learner was in their zone of proximal development.

As an example, a learner who was learning Chinese from English may repeatedly select the word *see* (in English or using a picture icon) and build a sentence using it. Each time the learner selected the word *see*, the computer replaced it with the Chinese word *kàn* and drew the attention of the user to this Chinese equivalent. After sufficient number of exposures to the replacement process, the computer hid the word's English translation and its icon, and required that the user select the word in Chinese.

Later in the learning process, the same learner may create a sentence *I saw him* and then add the word *yesterday* to it. In Chinese, the time adverb *yesterday* appears before the verb; so that the sentence becomes (Li & Thompson, 1989):

Wo	zuotian	kandao	ta	le.	(1)
I	*yesterday*	*see.completed*	*him*	*CRS*	
I saw him yesterday.					

In the beginning, the computer inserted the word *zuotian*, meaning yesterday, into the appropriate location between subject and verb, and drew the attention of the user to this insertion point. After sufficient exposures, the computer stopped automatically inserting the word, and instead required that the user manually determine its point of insertion into the sentence. In this manner, the learner was guided towards independent expressive competency in word selection, syntax and morphology.

Method

Objectives and Measures

Our objective was to investigate the feasibility of creating of a tool with which computer-aided scaffolding could be provided to language learners in teacher-less CLT environments.

In the absence of previous studies in CALL literature that established a benchmark for comparison in such an environment, we designed our experiment to validate *whether* effective scaffolding was possible, and not *how effective* the scaffolding was. Specifically, we did not design our experiment to compare how learners performed using our tool against how learners performed in a teacher-led classroom, nor against how learners performed when provided other tools.

Rather, our measures investigated whether the tool we created conformed to the theoretical framework we have described, in a teacher-less CLT environment:

1. Did the tool provide adequate support to learners to perform communication tasks above their current level of competence? This was measured by number of communication tasks completed by the learner.
2. Did the tool respond with adequate sensitivity to increasing learner proficiency by balancing demand and support? This was measured by studying the growth in the complexity of language used by learners.
3. Did the tool facilitate comprehensible input and reflection? This was measured by surveying the learners during and at the end of the experiment.

Participants and Procedure

We introduced the tool to 10 participants in India who were learning Chinese. The participants were proficient in English. Their age varied from 21 to 35. Four were female and six were male. None of the participants had any prior knowledge of Chinese.

Before starting the study, the participants were encouraged to study tutorials in Chinese phonetics and pinyin through internet resources. Pinyin is a standardized system for transliterating Chinese using Romanized spelling, and was used throughout the experiment; Chinese characters were not introduced.

Each participant was provided with an iPad on which the tool had been installed. They were given a brief tutorial (15 minutes) about how to use the tool.
The participants were then divided into random pairs, and each pair was given a social context in which to role-play. For example: introducing yourself to a stranger, ordering food in a restaurant, talking about your family.

Nine participants were required to sustain conversations (through their computing device) using the tool for scaffolding both encoding and decoding of meaning. After creating sentences using the tool, participants were required to vocalize the sentence by speaking in Chinese into the device. This speech output was sent to their partner via the tool, along with the sentence created. The partner was then expected to respond to the sentence. If they were unable to understand the meaning of the sentence from the speech output they received, they were permitted to use the tool to partially or fully decode the sentence for them.

One participant served as a control. This participant received scaffolding by an instructor in a traditional manner. This participant used the tool to communicate, but not to generate sentences. All participants were allowed to communicate only through the tool.

Study Design

Each learner participated in a number of sessions conducted over a time period of one week. Cumulatively, each participant used the tool for a duration of 90 minutes on average.
In the course of each session, the participants' use of words, word forms, and grammar relations were monitored, to evaluate whether scaffolding through the tool was resulting in greater language use. At the end of each session, participants were given a brief quiz.

At the end of the study, participants were asked to fill a survey, measuring the perceived level of effectiveness of the scaffolding received. Thus, the efficacy of the tool was measured through subjective feedback from learners as well as objective metrics of actual language use.

Process of Data Collection

We collected data in this study in three ways. First, online analytics were embedded into the scaffolding tool, to continuously monitor, record and transmit each participant's use of the tool. Second, we integrated quizzes into the tool that the participant had to take at the end of each session, and data from these quizzes was recorded and transmitted for analysis. Third, we administered an online survey at the end of the study to all participants. We discussed the process of data collection with all participants prior to the study, and obtained requisite permissions from them before beginning our experiment.

Results

We tested the generative tool in a virtual CLT environment. The language used by learners was measured quantitatively and qualitatively as a function of the duration of interaction with the tool. (As different learners interacted with the tool for different durations of time, the total durations are not uniform across learners.) Individual learners used the tool for between 46 minutes and 171 minutes. The results are shown in Tables 1 to 4.
Table 1 shows the cumulative number of sentences created by each learner as a function of time in minutes. The median number of sentences created was 31, compared to 17 sentences created by the control. Participants were able to create sentences and have conversations in the target language.

Table 1
Number of sentences created as a function of time

Participant	t=10	t=20	t=40	t=60	t=80	t=100	t=120
A	4	7	12				
B	4	8	16				
C	3	7	14	19			
D	3	7	13	21	31		
E	2	5	12	17	22	29	35
F	2	6	15	21	27	33	
G	3	7	15	24	30	38	
H	3	6	14	20	28		
I	2	7	14	22	28	33	

In Table 2, we observe the cumulative number of unique words used by each learner as a function of time in minutes. The median number of words used was 42, compared to 27 words used by the control.

Table 2
Unique number of words used as a function of time

Participant	t=10	t=20	t=40	t=60	t=80	t=100	t=120
A	9	12	18				
B	8	11	20				
C	6	12	23	28			
D	4	9	23	29	42		
E	5	12	24	32	37	47	52
F	5	16	31	39	46	52	
G	9	15	26	38	45	53	
H	5	7	16	24	39		
I	4	9	20	30	40	45	

Table 3 demonstrates the cumulative number of thematic relations used by each learner as a function of time in minutes. Unlike sentences and words, the set of thematic relations as captured by FreeSpeech is a small, finite set, numbering 23 relations. Learners using the tool used a median of 12 relations out of these 23, compared to 9 used by the control.

Table 3
Unique number of thematic relations used as a function of time

Participant	t=10	t=20	t=40	t=60	t=80	t=100	t=120
A	3	5	7				
B	6	6	11				
C	4	7	9	11			
D	2	3	6	7	13		
E	2	5	9	11	12	13	13
F	3	6	9	9	11	14	
G	5	6	9	11	12	12	
H	4	5	7	9	12		
I	2	6	8	10	12	13	

Table 4 shows the cumulative number of word attributes used by each learner as a function of time in minutes. The set of word attributes used in FreeSpeech is a finite set of 47 attributes. Learners using the tool used a median of 17 attributes out of 47, compared to 12 used by the control.

Table 4
Unique number of word attributes used as a function of time

Participant	t=10	t=20	t=40	t=60	t=80	t=100	t=120
A	4	8	11				
B	4	6	12				
C	6	7	12	13			

Participant	t=10	t=20	t=40	t=60	t=80	t=100	t=120
D	4	6	12	14	17		
E	3	6	13	14	16	17	19
F	3	10	13	13	14	17	
G	5	9	11	16	16	16	
H	4	5	10	13	17		
I	5	8	14	16	17	17	

On all four parameters we used to measure language output – number of sentences, number of words, number of relations and number of attributes – learners using the tool had greater scores than the learner who did not use the tool. In addition, the complexity of language – as measured by increase in diversity of words, relations and attributes used, consistently increased for all participants over time.

At the end of the experiment, the participants were surveyed to determine the perceived effectiveness of scaffolding received. All nine participants who used the tool reported that it facilitated improved quantity and quality of communication; had an appropriate balance of demand and support; facilitated comprehensible input in the target language; and provided opportunities for reflection and a sense of autonomy.

Discussion

Our objective was to build a tool that would scaffold learners in a teacher-less MALL environment with a focus on communicative competence.

As a baseline, we investigated the use of a machine translation tool as a scaffold and determined that while the tool provided adequate support to help learners complete tasks, and could respond adequately to increasing learner proficiency, it did not facilitate either comprehensible input or reflection.

The results indicated that our approach at creating a new tool, based on "building up" a sentence and incrementally translating it to the target language, performed better. The volume and quality of conversations that users were able to have with this new tool were comparable to the machine translation approach, with a substantial improvement in the comprehensibility of the tool's functioning, and correspondingly, reflection and autonomy.

Our study was limited by the small sample size (10 participants). With this limitation, the tool was able to achieve the scaffolding objectives we set out at the beginning of our study. It was able to maintain a balance of demand and support, by offering assistance in creating sentences while fading it away as learners advance. It was responsive to a learner's needs, monitoring their capability and assessing the gap between their current level and desired level. It was able to provide a novel form of assistance in helping learners with grammatical form and structure. This assistance was provided in a way that was consistent with the need for comprehensible input and reflection.

The result is noteworthy because it indicates the possibility of replacing at least one teacher role in a CLT classroom with a technological solution: the role of providing scaffolding to maintain learners in the zone of proximal development (ZPD). It is then conceivable to have a MALL application which is fully online, with peer collaboration and a focus on communicative competence, but which can scale to millions of learners without the corresponding need for a large number of teachers. This computational scaffolding also allows the incorporation of tasks, that have hitherto proven to be effective in a TBLT classroom environments, into a MALL environment, allowing for richer interactions and greater learning opportunities.

The study did not aim to compare the tool against other methods of scaffolding, and particularly did not measure learning outcomes when using the tool versus a teacher-led classroom. Our objective was to investigate the *feasibility* of scaffolding communication without a teacher, rather than measuring how well we could scaffold; this is a principal direction for future research. The tool did not also aim to provide technology analogues for *all* teacher roles – it merely investigated scaffolding. To create completely teacher-less CLT environments, further research is needed into computer implementation of other teacher roles too.

Conclusions, Limitations and Suggestions for Further Research

The study led to the creation of a MALL tool for scaffolding learners in teacher-less CLT environments, and validated both theoretically and experimentally that the tool scaffolded effectively when used to teach Chinese to English speakers. Our objective was to facilitate communication tasks in a digitally-supported CLT environment, where there is a gap between the learner's current level of competence and the competence required to complete the task. We set out to build a language assistive module to scaffold the learner to perform the task, and an adaptive control module that controls the level of guidance that the language assistive module provides to keep a learner in the ZPD. Our hypothesis was that these two technologies together would provide adaptive scaffolding to a language learner.

We developed a sentence-construction tool called FreeSpeech, which helps a user compose sentences using pictures by automatically supplying grammatical form. We developed an adaptive layer that would allow the learner selective access to FreeSpeech based on their demonstrated competence. We tested these two modules in a longitudinal study of 10 language learners, and found that the tool provided adequate support to the learners to perform communication tasks; responded sensitively to increasing learner proficiency; and facilitated comprehensible input and reflection. We thus concluded that the tool successfully performed computer-aided scaffolding for language learners in a teacher-less CLT environment.

A major limitation of our study was the small sample size involved: the study was performed with 10 learners, all of whom shared the same geographical location. An important area for future research is to investigate the effectiveness of our computer-assisted scaffolding techniques, particularly in comparison to techniques used by teachers in classrooms. Additionally, if further computer modules are designed to implement other teacher roles in a CLT environment, we may then be able to create truly teacher-less virtual CLT classrooms.

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