A CONTENT DELIVERY SYSTEM FOR COMPUTER AIDED LANGUAGE INSTRUCTION

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ABSTRACT

A Content Delivery System for Computer Aided Language Instruction

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North American children have a variety of cultural and linguistic backgrounds. For children whose mother tongue is still being spoken at home, maintaining and advancing parental linguistic instruction is an ongoing effort. This effort must be upheld by the parents and other classroom based media if the child is to preserve and further his mother language acquisition. We propose a means for computer assisted language delivery based on an expandable language content delivery system. The system is applied to the instruction of the Arabic language for grade one, second language instruction. All aspects of the delivery process are demonstrated in terms of letter shape, composition, recognition, connection shapes, and relevant vocabulary models. The model discussed in this thesis is relevant to the instruction of cursive languages such as Urdu or Persian. We drew on relevant research to enhance and contrast our system where necessary. A system designed based on the model gave rise to the creation of an engaging, user oriented interactive software application for the use of children at the grade one level. A total of seven students were asked to use the software and their interaction was observed and analyzed. The results of our experiments reveal acceptance and enhanced language acquisition as demonstrated by the evaluation experiments.

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Chapter 1 Introduction

1.1 Introduction

As children embark on the journey from childhood through adolescence, they are faced with multiple learning situations. Learning can take place at numerous occasions and levels, as a child ages. Several types of learning take place which help the child develop his thought processes, motor skills, speech, and other abilities. One form of learning could take place with the use of a computer available to a child.

The focus of this study is to assist immigrant grade one level children in the process of learning their mother tongue by developing interactive software system. The advantages of offering formalized instruction of a language, provided to students at an early age of about five or six, has been established in the study reported in [Zurawsky, 2006]. As a case study, we will explore the development and use of a prototype software by Arabic speaking children living in a predominantly English speaking country like the US and Canada. The premise for this attempt is that young children are progressively seeing and operating computers at younger ages. Additionally, language acquisition by children is gradual and the spoken aspect of a language is always acquired prior to the written one with very few exceptions. By the time the child has reached his first year of educational instruction, he/she has already acquired a fair amount of spoken language skills from his surroundings – mainly within the context of the family environment. The author of [Krashen, 1985] cites this kind of informal learning as 'comprehensible input' defined as "understanding input that contains structures at our next 'stage' – structures that are a bit beyond our current level of competence" as discussed in the study detailed in [Krashen, 1985]. Consequently, the child is assumed to be also ready for a formalized, advanced study of his mother tongue beginning at the basic levels of instruction, and as a continuation of prior informal parental language instruction and immersion, as per the findings in the study outlined in [Krashen, 1985].

At this age, the child is also simultaneously learning English as a primary language outside the family unit in the school environment, through friends, television, and other communications media. Considering the mastery of the English language of a typical child of immigrant background at age six at the grade one level, Arabic content will be delivered in English.

The intent to advance a student's linguistic knowledge using a computer tool incorporating a personalized delivery process for the child forms the basis and motivation of this research.

Formalizing the introductory aspects of learning a language consists of first defining its basic building blocks. For the purposes of this thesis, study of a single language curriculum at a grade one level is considered in order to identify the beginning blocks of the target language. The language of choice will be Arabic. An Arabic language curriculum will then be used to create presentation material for the proposed software system. Similar to our work, the authors of [Petrinjak and Graham, 2004] present a methodology of creating 'learning objects' from previously authored course materials so as to accommodate the pedagogical requirements of creating computer based-educational content. This serves to define what the content is, clarifies how it is to be used in similar endeavors, and identifies correct content sequencing. It is worth noting that while this study incorporates previously digitized material; our work digitizes the content of interest by using hardware enabling scanning relevant aspects of the curriculum of interest.

In contrast to adopting a pedagogical sequence from an already existing curriculum, the study reported in [McCormick, 2003] supports the removal of pedagogical concerns out of 'learning objects' to be delivered to students. The study advocates managing pedagogy within the realm of the learning environment in which the learning objects are accessed. This is accomplished for the purposes of creating learning objects containing more sophisticated, media-centered representations of content. Teachers accessing these objects must construct learning and assessment activities accommodating this design. Further, the nature of the learning objects, determines how they are to be used within the learning environment.

While the language delivery system will be applied to the presentation of the Arabic language, some of its founding principles we believe, can be applied to the instruction of any given language, as will be exemplified in the following chapters. Other aspects of the system such as connection shape modeling are best applied to cursive languages like Arabic is; as such, this connection shape modeling is most relevant to cursive languages. A *connection shape* is the cursive nature in which a letter appears once it is placed adjacent to other letters to create a two or more lettered word.

The devised system of language instruction lends itself to expansion in two directions of linguistic delivery. Firstly, it could be modified for delivery of another new language by applying relevant content authoring and delivery principles. This is termed *horizontal expansion.*

Secondly, the system can be expanded to deliver more advanced levels of linguistic instruction by way of incorporating more complex content-rich units into its delivery process, directed towards an older set of target users. This is termed *vertical expansion.* This facet of expansion draws on the core principles of the delivery system while incorporating more advanced content suited for a more mature set of users.

Both directions of expansion are based on the underlying linguistic delivery system devised in this research.

The basic building blocks of any language include the set of alphabets and the letter-to-sound rules required for pronunciations. The individual letters of the Arabic alphabet have structural shapes, sounds, and connection styles among certain sets of '*atomic shapes*' that compose the letter's shape. An atomic shape is a continuous line composed from connection points, forming any standalone shape, not separated by any spaces. This atomic shape is used in conjunction with other atomic shapes in order to create a letter. Each letter's atomic shapes are unique to the individual letter. Further, each of a letter's connection shapes is distinct from the others. In cursive languages, a word is composed of set of connection shapes belonging to differing letters. The study on Recognition of Cursive Writing reported in [Korani et al., 1996] investigates issues of character segmentation and recognition as will be modeled in our study of Arabic letter connection styles and shapes. In the study, segmentation of letters occurs using a 'segmentor' module which examines 'connected components' of a letter, and proposes several possibilities for recognition and identification of a letter. Similarly, our work adopts the segmentation concept and produces a set of atomic shapes and connection styles synonymous to the notion of segments

The Arabic language has 28 letters and 19 atomic shapes composing the entire alphabet. We propose that their structural shapes shall be described by means of a two-dimensional pattern-grammar. The way in which letters were written forms one unit in the curriculum considered. We present these rules using the BNF notation to produce a two-dimensional grammar of letter composition.

As with any elementary level language instruction, a relevant set of vocabulary is acquired by the student to set the way for proper verbal and written communication. Only relevant, 'age-appropriate' vocabulary will be included in the vocabulary model, as prescribed by the authors of the study [Zurawsky, 2006]. Successful acquisition shall be measured with evaluation sessions. Feedback to the child is provided in audio video emotion or expressions.

1.2 Thesis Contributions

This research is concerned with development of a language delivery system for children at the grade one level for the purposes of delivering a formal education of a child's parental language. The following is a list of contributions yielded by my research and study of this subject area.

a) *User Model*: A student model of a child of this age group in terms of characteristics and behavior. This behavior is identified based on observations made during content acquisition sessions within the classroom, conducting informal interviews with children of this age group, questioning preferences for presentation styles and feedback upon performance. This is also complemented by observing another set of students engaged in a computer game.

   Based on observations and information collected from this age group, it seems evident that children respond best when credited with positive audio and visual feedback upon correct performance and become more attentive upon gentle reminders to pay more attention to the instruction currently provided. These findings were then incorporated into the content delivery process developed in this work. The study discussed in [Zurawsky, 2006] stipulates that any new language instruction must be 'age-appropriate' in order to address to the needs of the age group under consideration. 'Age appropriate' instruction shall be incorporated into our work by taking into consideration the typical profile of children belonging to the target age group, as embodied by the user model.

b) *Practical Language Delivery*: The user model gives rise to another main contribution of the thesis; providing a practical example of language delivery modified by user expectations and preferences, allowing for a learning experience that minimizes the overhead and difficulties that children often face when learning written and verbal language skills of a spoken language. The interactive nature of computer based applications leads the way for such an experience.

c) *Authoring Linguistic Content:* A method for authoring and delivering linguistic content using our student model is also introduced. The content to be delivered is extracted from a given grade one curriculum, and a subset of that curriculum is incorporated into our language delivery tool. The subset of selected content is chosen based on the target age. The amount of content as it compares with the acquisition and comprehension abilities of the age group under consideration is another element relevant to content authoring techniques studied in this research. Further, only a subset is considered because boundaries must be placed on the amount of content that is to be delivered by any content delivery process.

d) *Letter Recognition and Compositions Template:* The content model discussed in this thesis provides a template of knowledge focusing on letter recognition and composition techniques, sounds, and connection shapes, and associated vocabulary. We will first introduce each of the twenty eight standalone Arabic letters. Arabic letters can assume different shapes, depending on the part of the word the letter appears within. For this reason, each standalone letter is associated with three possible connection shapes, introduced within the context of related words, as well as other graphical and audio delivery tools to define a letter's sound and visual appearance.

e) *Two dimensional grammar for letter shapes:* A two dimensional grammar defining composition rules was created by examining the twenty eight Arabic letters for atomic shapes composing each of the letters. There were 19 such shapes. Visual examination of each standalone letter and dissection of its atomic shapes gave rise to its composition rule. For each letter's composition rule, shape proximity, relative location and size were taken into consideration and incorporated. Terminology and graphical representations describing shape positioning will also be introduced. A similar two dimensional grammar describing letter connection shapes within words is also put forth.

f) *Relevant Vocabulary:* A set of vocabulary words is then introduced to the student. Having learned all the letters of the alphabet, and how they appear when connected to others within a word, and the ability to recognize a letter, a student is then ready to learn the meaning and spelling of new words. Vocabulary meaning and spelling are associated with words by way of relevant visual aids, containing the word written out and a visual representation of what the word means. Each vocabulary word will be associated with a letter with which it is phonetically associated so as to reaffirm a students' knowledge of each letter shape and sound. When the first letter of the word is a given letter sound, there exists phonetic association between the letter and the word. After being introduced to a minimum of 84 words showing all possible 3 connection shapes of 28 alphabet letters, a student is then asked to compose a subset of 28 words.

Based on the knowledge previously acquired, all possible letters along with their connection shapes are presented to the student. The student should then be able to choose which letters, and what corresponding connection shapes, are to be used when composing a given word in a work area.

During the process of composing an entire word or inserting a missing letter within a word, a student is either rewarded with positive audio and visual cues upon choosing the correct letter connection shape to place his work area, or is rewarded with negative ones upon choosing the wrong one. When a student correctly completes the spelling of the entire word currently under study, he/she is again rewarded with positive audio and visual stimulus. This sequence of operations of the delivery process is in sync with the user model for this age group. It serves as an example of content authoring and delivery methodologies contributed by our work.

g) *Alphabetic Shapes Repository*: The 84 basic words introduced during the letter shape and sound section do, in fact, compose a complete set of Arabic words with respect to all possible letter connection shapes. In other words, all possible shapes of the 28 Arabic letters are included in this subset of words from the Arabic language. This contributes an alphabetic shapes repository containing all possible shapes for all letters to be referenced by subsequent instructional strategies.

Modeling Arabic introductory content in this thesis shall explore new methods of representing elementary linguistic content applicable to similar, cursive languages. It will also introduce concepts broader in scope and applicable to the instruction of any language. It will also provide a framework of linguistic delivery system expansion, relevant to more advanced areas of linguistic instruction.

The evaluation tasks were used to test how well a user has learned. It presents the student with a guided evaluation process, in the form of suggestive work area templates which narrow the possibilities of user input to correct ones. For example, in the word composition tasks, children can infer the correct response based on the number of boxes appearing before them on the work area, on the visibly suggestive nature of the letter connection shapes, and by referring back to prior interfaces delivering content under consideration. English transliterations of Arabic words embedded within images helps the student to phonetically decipher words as he/she pronounces them and hence assist the student in word composition tasks.

The process of analyzing letter shapes for atomic shapes and extraction of an alphabetic composition grammar is applicable to the study of any other language. Moreover, vertical extension of the linguistic delivery system devised in this work could lend itself to delivering Arabic content at different levels of instruction to different age groups.

h) *Content Delivery Application:* We also developed an application of the language delivery system proposed in this work, which we will call 'AlifBaTa Teacher'. The development process followed the Personal Software Process (PSP) as outlined in the study described in [Silberberg, 1998] in order to deliver the final Arabic teaching application to grade one students. The PSP software development process is applicable to the development of small applications by a single developer.

Software process models such as the water fall model are used in the development of large software involving a team of developers. This thesis work, on the other hand, involves one developer, and for this reason the PSP was chosen as the appropriate software development process to follow. In PSP, each desired behavior of the resulting code is written in pseudo code which is then implemented in the target programming language. Once completely developed, the software was evaluated on a total of 7 grade one children and their feedback was recorded and used as a basis for any further revisions and improvements of the software and underlying system. The evaluation results will be used to assess the content authoring, delivery and user modeling strategies devised in our efforts. Through its application of the PSP process to developing the resulting software, this work demonstrates an example of a scientific application of a personalized software development process in order to yield a set of conclusive test results, for the purposes of verifying our research methodology.

We assume a child can use a mouse for input, although a pen device or at least a touch screen would be more appropriate. The output will be based on both display and audio feedback.

1.3 Organization

This section describes the organization of the rest of the thesis. Chapter 2 reviews related work in areas relevant to this research. They include computer aided language learning, CALL, learning content management systems, LCMS, handwritten character recognition, and phonological awareness to increase letter and word associations.

Chapter 3 describes the proposed content delivery system in detail. In particular, we delve into the student model used as a basis for customizing the linguistic delivery process and use the Arabic language to illustrate our approach to applying the content delivery system.

Section 3.4 outlines details of the linguistic delivery system devised in our work and discusses the benefits of letter modeling techniques. This is followed by a study of the benefits and applications of letter connection shape modeling as well as advantages of the modeling principles adopted in our work. We will also describe letter composition and connection models, BNF notation and position operator specification, atomic shape extraction from the alphabet and atomic shapes, and BNF two dimensional grammar dictating letter composition and connection rules.

Section 3.4.5 introduces a vocabulary model based on the 28 Arabic letters introduced, drawing on the phonological similarity study to associate letters and phonetically associated vocabulary.

Section 3.5 discusses possible expansion schemes for the linguistic content delivery system constructed in the previous sections. Section 3.5.1 defines vertical expansion for the same language, different level of delivery while section 3.5.2 discusses horizontal expansion so as to apply the delivery system to other languages.

Section 3.6 puts forth a detailed comparison of related work to our research, by presenting similarities, differences, and drawing conclusions regarding the incorporation of the related work into our efforts.

Chapter 4 outlines the development process of the application implementing the linguistic content delivery system according to the PSP process. This process includes PSP0, for outlining the task specification process, PSP1 for outlining task and schedule plans, resource specification, program size, defect report generation and compile time, and PSP2 for investigating review techniques and design completeness criteria.

Concluding remarks are provided in chapter 5, followed by some recommendations for future work.

Chapter 2 Related Work

In this chapter, we first provide a comprehensive study of existing areas of relevance to our study and we discuss their significance and contributions to the advancement of science and technology in their perspective areas. We also discuss how each work is related to and influenced our current study.

2.1 Computer Aided Language Learning for children (CALL)

The author of [Warschauer, 1996] discusses the progress of CALL related research over the past thirty years. He puts forth pedagogical issues that educators must contend with when developing CALL based applications, and steers away from discussing technical software or hardware related concerns in this subject area. Pedagogical concerns are also addressed in the study described in [Bowerman, 1992] within the context of the tutorial module, in which the teaching framework and operations are set up and executed.

The study reported in [Warschauer, 1996] firstly outlines the developmental phases which CALL research has undergone over the past years. The phases are labeled as follows: behavioral CALL, communicative CALL, and integrative CALL. These phases are not exclusive of each other, but rather one phase is incorporated into the next.

A discussion of behavioral CALL is in order. Behavioral CALL is based on behaviorist theories of human learning, and emphasizes repeated exposure to linguistic concepts on a computer based application. Repetition in a computer environment is not a major concern due to the speed of processors, and the student can progress at an individualized basis, even with repetition. However, the underlying principles of behaviorist CALL theories were undermined when behaviorist approaches to languages learning were discarded at both the theoretical and pedagogical levels.

The next phase, communicative CALL, rejected the notion that repeated exposure to content served value to instructing language principles. Rather, the prominent thought at the time focused on communicative teaching by reinforcing ideas such as forms usage, implicit instruction of grammar, and avoids instant and negative feedback to students of a CALL based application. This concept builds on student motivations for learning and encourages learner-learner and learner-computer interaction. Several examples of communicative CALL based applications include material for paced-reading, text reconstruction and language games. As with the behaviorist model of CALL applications, the computer is perceived as the provider of the right answer. This notion was termed *computer as tutor*. This is synonymous to the notion of "tutoring model" coined by the author of [Bowerman, 1990], which specifies this module as the one maintaining and executing the teaching operation of the CALL application. This concept still holds in communicative CALL based applications as it did with behaviorist ones. However, compared with behaviorist CALL applications, there is a considerable amount of student interaction when arriving at the correct answer for a given linguistic question. Another CALL model introduced in this face is *computer as stimulus*. In this model, rather than driving the student to arrive at the correct answer, he/she is encouraged to undergo an exploration process when arriving at the correct answer. This is similar to the concept of 'interface model' introduced by the author of [Bowerman, 1990] which the student uses to interact with the software and receives feedback based on performance. The last model of CALL employed by this phase is the concept of *computer as a tool,* where computers play the role of allowing users to understand or use a language.

Communicative CALL was seen as not fully exposing the real potential of CALL based applications; experts noted that CALL based applications were being used in an ad hoc fashion, compartmentalizing linguistic instruction and searched for a more integrative approach.

The integrative process relies heavily on multimedia in the form of graphical, text, sound, animation and video. In addition, hypermedia technologies are employed which link resources together and allow learner navigation. This advance allowed for real world learning simulation and simultaneous skill integration, where seeing and hearing are coupled. Reading, writing, speaking, and listening are all possible at the same time. This also provides students complete control over his content browsing. These tools were employed by the creation of a CALL based application named Dustin as discussed by the authors of [Warschauer, 1996].

While the advantages of hypermedia browsing are evident, the creation of CALL based applications still may possibly rely on teacher authoring of language teaching tools. This is a drawback as educators normally lack the time and expertise required to create effective CALL based applications. On the other hand, commercial developers of language teaching tools may lack the pedagogical skills required to effective language teaching tools. The fact that computers are not yet fully interactive as they do not evaluate the content of linguistic skills such as speech is also brought forth. The article finally concludes that some form of AI must be employed for this objective to be achieved. Another improvement is computer mediated communication tool, whereby learners of the same language can collaborate to learn.

The study reported in [Koper, 2001] describes a solution for this dilemma by introducing a method for effective pedagogical modeling of content within the realm of educational modeling language (EML). This is accomplished by putting forth a multitude of pedagogical meta-models analyzing a series of pedagogical models. Each pedagogical model describes instructional design of 'units of study', or content to be delivered.

Correspondingly, the study outlined in [Petrinjak and Graham, 2004] addresses this concern by taking a pedagogically oriented approach to content delivery, rather then focusing on technical aspects of the delivery process.

The study reported in [McCormick, 2003] focuses on teachers as users of the content delivery system, as manifested in the CELEBRATE project. This study takes into consideration teacher usage needs when authoring content for teaching in the form of learning objects; needs such as time for creation, evaluation, searching, and entering of learning objects into any content delivery system.

2.1.2 Learning Content Management Systems

There have been continued efforts in the domains of content delivery and authoring for educational purposes. In this context, researchers of the study discussed in [Brooks et al., 2005] focused on the development of online educational software intended for meeting content authoring and delivery objectives for a distance education or a beginner computer science course. This was an effort to create a learning object content management system which resulted in introducing a learning object sequencing environment, content delivery engine, and an assessment application. This endeavor required carefully crafting content for easy accessibility and information delivery, while allowing users the opportunity for self learning and performance evaluation. After a brief exploration of available content delivery methods, the authors attempt to develop both the content and delivery tools and describe the multitude of issues involved in this process.

Methodology in creating this content management system required incorporating e-learning principles. Firstly, content is organized into 'content packages' made up of four parts. Secondly, the manifest file outlining the package metadata is created. It composes a set of organizational hierarchies describing the arrangement of smaller units of knowledge, references to relevant digital assets, and sub-manifests which supports nesting of packages within one another. Information within content packages breaks down large learning content into small pieces. In this context, different paths of learning can take place depending on the learning hierarchy under consideration. While there are provisions for specifying learning paths for any given learner, there is no mechanism for dictating which path users can see. These provisions are based on factors controlling content access such as score results and learner progress conditions. These are maintained through a tracking model, synonymous to the concept of user modeling in related literature and this study.

Content design involves authoring and sequencing the course material to be delivered, and a delivery engine which works to render learning content and control access. The concept of simple sequencing is introduced, discussing which content should be introduced to the user under which conditions, so as to control the order of content delivery.

This research addresses the issue of learner modeling used to support adaptive instructional material. Previous research puts forth differing kinds of learning models varying in complexity and user insight. The unique contribution of this work is linking content and users by keeping track of user preferences or competencies.

2.1.3 Handwritten character modeling

This patent study reported in [Leigh, 2005] focuses on the notion of decoding hand written characters. The proposed methodology starts by comparing any given hand written character with one of a series of internally stored character models. A given input character is decomposed into a series of segments composing that handwritten character. Character decomposition into segments is done in accordance with a segmentation scheme for each character model. Segmentation schemes decipher handwritten characters by partitioning each stroke into a series of sub-strokes. A minimum stroke length is upheld in order to avoid considering strokes which are too small to be relevant to the handwriting under consideration.

Further, input character decomposition into segments is evaluated against the segments model corresponding to a given character model currently under consideration. Each stroke of a handwritten character is segmented into a series of sub-strokes. Sub-strokes undergo a feature extraction process for the purposes of pattern specification process. More specifically, handwritten strokes are segmented into letters or sub character primitives according to handwriting restrictions such as pen-ups or cusps. Each hand written character stroke is decomposed based on the expected structure of the current character. For this reason, a generic handwriting segmentation schema is not used. The segmentation methodology is character specific.

A score is assigned to the handwritten input character which indicates the degree of conformity to any internally stored character model currently under consideration. Evaluation of a character's segments could possibly take place against several character models until a character model most closely resembling the character under consideration is selected. If an input character cannot be segmented in accordance with the segmentation scheme of the current character model under consideration, then the input character is deemed not matching the current character model, the segmentation procedure is abandoned for efficiency, and another character model resembling the current one is considered.

Segmentation points connect segments of a stroke. Certain characters are written in a similar way, and for this reason, similar segmentation points common to two or more letters are cashed to reduce segmentation overhead of similar characters. Also, if a simple handwritten character is not segmented and immediately identified with the current character model under consideration, then the current model is rejected and the next one is considered to reduce overhead and increase efficiency of character identification.

Character models are assigned only to letters, numbers or, punctuation marks.

It is also possible for any given character model to have multiple segmentation schemes in order to accommodate different forms of the same character. Further, one segment could be broken into several parts due to bad handwriting. For this reason, error detection of segments must be accounted for, and rules which detect this must be devised and used in order to determine any given symbol. In addition, a context sensitive analysis of the handwriting characters is performed in order to identify the intended meaning of any given character. More specifically, each stroke and sub-stroke composing a character is also interpreted in terms of its context for proper identification of its role.

2.1.4 Phonological awareness and phonological similarity

Given that letter knowledge and awareness are the two main predictors of a child's reading ability, the researcher in [Jong, 2007] performed an analysis of letter-sound learning in kindergarten children. The premise of the study is that association of letter sounds, previously associated with a written symbol, with recognizable words, starting with that sounds, facilitates the acquisition and association of a letter symbol and sound. This is called phonetic similarity. The work concluded that children benefited from the letter names and sounds which were phonetically linked. Another supporting study revealed that letters with embedded phonetic similarity, whose names contained the letter sound such as 'm' or 'p', were acquired at a faster rate than letter names which did not contain the letter sound such as 'y', as indicated by the study reported in [Jong, 2007].

All studies referenced in this paper reveal that letter sound-knowledge increased when words associated with the letter sounds were introduced. The word-letter association was that the first sound of the word, the phoneme, was similar to the letter sound. The associated words used were familiar, one syllable, and used with high frequency.

Based on the first premise that associating a letter's sound and the first sound of a familiar word improves letter-sound learning, another premise was introduced. It was suggested that the difference in knowledge acquisition between two groups, one possessing phonetic similarity and the other not contain it, would vary depending on the ability to extract phonemes.

The methodology of the study was to teach two groups of children a set of four letters, and their corresponding sounds. First, the students were introduced to four symbols, and then each symbol associated with its corresponding sound. This was accomplished when in an experiment; the students were shown four symbols and named each one out loud. During the presentation trial, for one group of children, a further association was made between each letter taught and one familiar word starting with that letter. The other group of children were not provided with such an association.

Children in the word-symbol association group were asked to repeat the words associated with the letter sound to ensure correct pronunciation of the words. Subsequently, during the test trial, the first test was administered to examine the children's symbol-word knowledge. Each symbol was shown to the children and they were asked to provide the word phonetically corresponding to that symbol. This was followed by another presentation trial, followed by seven test trials.

Further, to assess the results of the experiment, extra measures of vocabulary, letter, and phonetic awareness acquisition were administered.

Experiment results revealed that the group of students introduced to words phonetically associated with a letter acquired letter-sound knowledge at a faster rate than the group missing such an association. This finding was in accordance with earlier research studying the benefits of letter sound association with letter names on letter sound learning. It also found that relearning the letter after forgetting it was occurred more efficiently in the group receiving word-picture association. This leads to the conclusion that phonetic similarity between two sounds increases the likelihood of their association.

2.2 Discussion of related work

The author of [Jong, 2007] shows how CALL research leaves behind behavioral CALL as new language learning models emerge, and opts to adopt more advanced pedagogical and theoretical learning models. CALL research also diverted away from communicative CALL as it was perceived as not providing a systematic, thorough approach to creating and using CALL applications. This lead to the need for more integrative methodology which resulted in a strong shift towards the development of integrative, engaging CALL applications, supported by advances in multimedia technologies. Seeing, hearing, speaking, reading, listening and writing were integrated into one application in order to simulate real world learning situations. This shift also takes advantage of a new navigational technology of hypermedia. CALL research reconciled pedagogical and technology related application creation concerns by incorporating AI technologies. This combines teacher expertise on the subject area with technology required to create such applications.

The study detailed in [Brooks et al., 2005] investigates learning management systems and isolates three key components required to create a successful content delivery management system, a content sequencing system, a delivery module, and assessment application. Content is to be divided into packages to be delivered, and that content is described by means of manifest files outlining content hierarchies, relevant material and sub-manifest files describing content nesting. This ultimately leads to different learning paths to be taken, and are kept track of by way of tracking models. In this schema, content must be sequenced and consequently delivered according to this sequencing scheme. User preference or competencies are incorporated and kept track of with user models.

The study on handwritten recognition described in [Leigh, 2005] reveals that the recognition process involves comparing the characters under consideration with internal, predefined schemes of letter composition. The main notion is that characters are decomposed into segments composing those characters, and each segment is compared with the corresponding segmentation scheme of a character model. The degree of conformity to a characters segmentation scheme is kept track of with a score. If this score is too low, then the next character to be considered is compared with the current written character to be deciphered. Segmentation cashing is used as a way to reduce the overhead of decoding similar characters. Different character segmentation schemes must be devised so as to accommodate differences in handwriting. Context sensitive segmentation is performed in order to realize the intended meaning of characters, which in turn saves overhead in segmenting the character.

The author of [Jong, 2007] studies phonological awareness and use of phonological similarity. He notes that creating an association between letter sounds, linked with a written symbol, and familiar words starting with that sound increases the likelihood of acquiring letters sound and symbol association. This is called phonetic similarity and assumes the ability to extract phonemes from a given word. The words to be associated are to be familiar to learners and relevant to the age group under consideration.

This finding was based on experiment results showing that children introduced to words phonetically related to a letter performed better when tested on letter-sound knowledge.

2.3 Incorporation of Related Work

Our research venture adapts, combines, and builds on aspects of the above mentioned.

When considering creating a model based approach to creating a language delivery system, we study the diverse field of CALL research, and consider the study reported in [Warschauer, 1996] for solutions to relevant issues arising during the system development process. This is because CALL related research offers the same founding principles required to deliver a sound language delivery system aimed for the age group under consideration. Our research adopts CALL concepts developed over the past thirty years of research and development, applicable to systems of linguistic delivery. Animated, audio, visual, and content authoring tools were employed in the creation of the delivery process. Basic language development tasks such as alphabet composition and reading, word creation, and vocabulary acquisition were other core CALL concepts adopted by our system of linguistic content delivery.

Our effort also lends itself for comparison and incorporation of 'learning object content management systems' research related in [Brooks et al., 2005]. Having identified linguistic instruction as the content to be delivered using our system and the resulting tool, a management system for the content must be devised for effective and meaningful delivery. One such delivery tool introduced in this research is the concept of 'content packaging', in which units of knowledge encapsulating content are created for delivery. It is synonymous to the notion of atomic shapes introduced by our study as a practical method used for letter recognition and composition evaluation. Atomic shapes are extracted from the alphabet after decomposing all letters into common, composing shapes. Each letter's composition was described using a two dimensional grammar describing atomic shape selection and positioning within a given work area.

The two dimensional grammar describing letter composition rules relates to the notion of manifest files defining the organization scheme of the content packages, as described in the related study. This is another facet of incorporating this related work.

This study of related work also introduces the concept of simple sequencing. It is a tool used to organize the flow and delivery of content. After isolating the kind and amount of content to be delivered by our system, simple sequencing strategies were used to organize the delivery of the linguistic content under consideration in this study. The notion of user modeling technologies discussed in related work was also used to personalize the delivery process.

After considering the kind of content to be delivered, content specific delivery tools discussed in related research serve to enrich our delivery process. More specifically, the phonological awareness and similarity principles applicable to alphabet shapes, sounds, and associated vocabulary delivery discussed in the study reported in [Jong, 2007] are incorporated into the delivery process of our research. This study suggests an association between letter sounds and phonemes, the first sound of a given word, as a way to enhance student learning and acceptance of new material. This also serves as a suitable basis of a method for introducing a new set of alphabet letters, and associating their sounds with phonetically related vocabulary as is performed in our study.

The research discussing handwritten character recognition outlined in [Leigh, 2005] introduces a methodology for decoding handwritten characters based on segmentation schemes. The concept of character recognition based on decoding of sub-strokes composing that character is synonymous to the process of using a set of atomic shapes to compose a given letter of any alphabet. After being introduced to the sounds and shapes of any given alphabet, an evaluation scheme incorporating the concepts behind this related research is devised. One aspect of the evaluation process tests letter composition abilities by prompting students to compose any given letter using a set of previously extracted atomic shapes. Drawing on this similar research enriches the evaluation process of our language delivery system.

Chapter 3 Content delivery system

In the previous chapter, we reviewed the work relevant to this research. The current chapter outlines the development methodology of the content delivery process proposed in our work, as well as a comparison with the related work.

3.1 Student Model/ Immigrant child Profile

When delivering an intended curriculum we must consider the characteristics of a typical learner group for grade one level. This is useful for personalization of the content and its delivery process to the needs and mental and physical capacities of a child of this age group. In this work, we consider as learners immigrant children whose mother tongue is Arabic and are in grade one in the age range 5 to 6. The language delivery system and resulting application are both user centered. In contrast, similar research on 'learning object' conception, the study reported in [McCormick, 2003] focuses on teacher rather then the student needs when devising content to be delivered, as teachers are seen as the main drivers of the pedagogical learning experience of the students.

Students of this age group are assumed to have certain skill sets acquired through prior learning endeavors, based on observations at their home environment, parental instruction, prior formalized forms of schooling, or interaction with other children. This basic, presumed skill set is what will be outlined in this section and an explanation will follow showing how each skill will be applied as a student interacts with the application delivering basic Arabic linguistic content of grade one level. These characteristics were recorded while children interacting in a grade one level classroom environment were observed and consequently interviewed. Computer usage aptitudes and tendencies of typical children of this age group were also solicited from a child interacting with an online computer game. These findings form the basic assumptions of the student model to be put forth in this section.

In this work we assume a child of grade one level has the following set of skills:

1. Has the mental capacity to memorize basic sequences such as, counting from 0 to 10
2. Has the mental capacity to recognize simple numbers, from 0 to 10.
3. Has the mental capacity to recognize colors and associate each color with a name.
4. Has the physical and mental capacity to use a pointing device, or a mouse to drag and drop virtual objects to a specified location. This entails the ability to click a mouse, and consequently, drag it to given location. This requires a sequenced cognitive process on behalf of the child, coordinating physical and mental abilities to successfully complete the operation.
5. Can recognize graphical representations suggesting scrolling to the left or right and click on buttons containing those representations.
6. The software interface developed presents five letters at a time. A student must click on scroll buttons in order to see other letters of the alphabet. Therefore, a student must have the ability to synchronize counting and clicking actions so as to arrive at the correct letter after being instructed to click a number of times to get to any given letter.
7. Has the mental ability to visually recognize positive feedback, and get satisfaction from such a feedback.

8. Has the mental ability to recognize positive audio feedback associated with a positive visual one.
9. Has the mental ability to visually recognize negative feedback, and strive for better performance as a result of receiving such feedback.
10. Has the mental ability to recognize negative audio feedback associated with a negative visual one.
11. Has the mental capacity to recognize a familiar voice such as his/her parent's or another child's voice when providing a positive or negative feedback on performance. Such familiar voice based feedback is expected to have more impact on the child's learning process.
12. Has the mental capacity to recognize happy/positive emotions displayed as a graphical face on the screen
13. Has the mental capacity to recognize sad/disappointed/negative emotions shown by faces.
14. Has the ability to extract the phoneme from any given word, that is, to extract the first sound of a word and associate it with a letter.
15. Has the ability to recognize a letter sound within a word, in order to realize its relative location within the sound of the entire word, this is termed '*phonetic extraction*'.
16. Has the mental capacity to recognize letters contained within a word, learn a letter's shape, and recognize the same letters with that shape within a another word.

17. Has the mental ability to cognitively compose a letter from a set of atomic shapes and produce the letter shape through drag and drop operations.
18. Has the mental capacity to recognize and extract similar shapes and patterns in letters or words.
19. Has the mental capacity to realize which letter is missing from a word that is partially spelled based on prior learning, and phonetically associating each letter sound with a shape upon examination of a word.
20. Has the mental capacity to recognize a named letter among others when they are displayed to him/her.
21. Has basic command of the English language.

We also assume students of grade one level have the following characteristics:

a) Low attention span. For this reason, every aspect of the system under development presents a child with a limited amount of information at a time
b) Responds to a parent's or child's voice scorning when they make repeated or major mistakes.
c) Responds positively when parents or child's voice congratulate student for successful completion of tasks
d) Strives for consistent successful task performance as a result of receiving both positive and negative feedback when he/she completes tasks as he/she interacts with the software.

The default operation of the software implementing the student model outputs a child's voice for feedback. Alternatively, each student's parent will be asked to provide audio files to be incorporated into the application so as to personalize delivery and improve acquisition of knowledge. The messages to be recorded are both positive for good performance and negative for poor responses.

3.2 Content Model

In order to define the building blocks of the language to be taught to a child, we examine the content of existing grade one level linguistic curriculum. As a case study, a grade one Arabic curriculum will be modeled and used for delivery in a software application which we will develop as part of his research. This section discusses issues related to the content model and delivery strategy.

3.2.1 Content Modeling Strategy

Some of the modeling principles arrived at as a result of examining the Arabic curriculum will put forth an abstraction of concepts applicable only to the instruction of similarly cursive languages such as Urdu or Farsi. In particular, letter connection shape modeling is most relevant to letters when they are written in cursive style. Other modeling principles such as atomic shapes, vocabulary introduction, phonetic association and word composition are applicable to the modeling of any other language at the elementary level. These aspects of the model are relevant to all language instruction based on the assumption that all languages are taught similarly, using a bottom up approach. Letters, sounds, and vocabulary are the introductory content in any grade one level. Their instruction, we believe, can be approached in a similar way regardless of the language under consideration.

The first step is to visually introduce all the 28 Arabic letters associate each letter with a sound, its three possible connection shapes, and three sample words in which that letter appears. This step presents the letter within the context of three words, visibly and phonetically containing that letter at various parts of the word. When applicable, a word contained the letter sound at the beginning, another one at the middle, and the third at the end, corresponding to each of the connection shapes. The words used in this section are familiar and relevant to the age group under consideration. A phonetic similarity study described in [Jong, 2007] suggests a beneficial relationship between word familiarity and quality of letter acquisition by the student.

The study examining the relationship between phonological awareness in kindergarten children has approached teaching the letter sounds in a similar fashion. Similar to our research, the study on phonological awareness and letter sound learning approached letter learning by associating sound and words with a given letter. The study concluded that the notion of phonetic similarity between a letter sound and the first sound in a given word facilitated the acquisition of that letter and its properties such as sound name and symbol. This related work validates the Arabic letter delivery methodology mentioned previously.

The interactive software tool we have developed displays five letters at a time of the alphabet set. Upon click on any one letter by the student, each letter is pronounced, so as to associate each letter with its corresponding sound. Upon clicking on the words related to each connection shape, the word is also read out by the application. This increases the likelihood of phonological similarity discussed in an earlier study reported in [Jong, 2007].

3.2.2 Benefits of Letter modeling

An ideal method of interactive input would be a touch screen. A touch screen could act as a paper and the child's finger as the pen. The shapes the student makes on the screen are the same as those he/she would make using a paper and pencil, and consequently, accurate judgment of his letter composition skills. However, the incorporation of a touch screen into a language teaching tool is not feasible for reasons of time and cost in our case. In the absence of this hardware capability, another method must be devised to test how well a student can recognize and compose letters. A model consisting of atomic shapes and composition rules can help evaluate a child's ability to compose letters. This is accomplished by extracting a set of atomic patterns, composing all the letters of the alphabet, and then verbally prompting the child to implicitly apply one or more of the letter composition rules to those patters. Evaluation of the patterns and the corresponding composition rules, to be introduced, which the child chooses to apply, yields a method to assess a child's letter composition abilities.

After hearing and viewing the letters of the alphabet and their corresponding founding atomic shapes, students are able to apply this acquired knowledge to the composition of letters and words. Viewable content in this form is similar to that of the study on observational learning on preschooler's alphabet knowledge described in [Horner, 2001]. That study proves the existence of a strong correlation between viewing 'print' of the alphabet and recognition of upper-case letters upon evaluation. This validates the evaluation methodology introduced in our work in which the letters of the Arabic alphabet are firstly introduced, diagnosed for atomic shapes, and consequently student letter composition and recognition abilities are measured.

The isolation and grammar created for the atomic shapes of the alphabet under consideration is similar to the work done in the study of decoding handwriting characters reported in [Leigh, 2005]. In that study, each possible handwritten character is associated with a set of segmentation schemas which identify that character's model. The segments are synonymous to the concept of atomic shapes introduced in this paper, and the segmentation schema is synonymous to the two dimensional grammar applied to the atomic shapes in order to produce all the letters of the alphabet. The notion of a two dimensional grammar dictating the authenticity of letter composition is synonymous to the expertise module described by the authors of [Bowerman, 1992]. In this work, the expertise module 'contains the system's knowledge of writing', in other words, this specific module is used to verify student German writing according to a pre-existing set of grammar rules for text and sentences. In the same way, the two dimensional grammar of our study directs the verification process of letter and word composition models devised in our work.

Further, the authors of [Petrinjak and Graham, 2004] refer to the concept of 'metadata' describing 'learning content'. In this study, metadata describes the structure and operation of 'learning objects', much in the same way that the two dimensional grammar of our work describes letter composition and connection shape content.

3.2.3 Benefits of Letter Connection Shape Modeling

Modeling letter connection shapes provides a basis to create a tool to teach and evaluate student letter connection abilities, and ultimately, his ability to compose words. The content model puts forth a two dimensional grammar describing how each letter of the alphabet connects to adjacent letters. In practice, this model is implemented in the resulting application by presenting the child with all possible connection shapes of a letter and allowing him the opportunity to venture upon creating one previously learned vocabulary word at a time. Instant feedback is displayed upon each drag and drop operation of letters, and correctly placed letters and the number of attempts made to give a correctly written and spelled word. Letter recognition, letter connection, and atomic shape models are the basis for evaluating the child's performance.

3.2.4 Modeling Principles

The main concepts introduced for this linguistic level include: (1) Letter shapes and sounds introduction (2) Letter composition (3) Letter connection modeling, and (4) a vocabulary model representing the basic words and their meanings to be introduced to the student. The first one is exemplified through studying an Arabic language curriculum for grade one level. The study reveals a model for analyzing letters and composing a model for representing their shapes and connection styles. The model is arrived at by visually inspecting letter standalone and connection shapes for atomic patterns and extracting composition rules to be applied to those shapes. For letter connection shapes, composition and connection rules are defined for each letter connection point: beginning, middle, or end, relative to the word under consideration.

We will use Backus-Naur form (BNF) as the model description language to present the language syntax. Studying letter connection shapes introduces the student to a set of words containing the letters under consideration. The next modeling principle draws on those already introduced words to expand student's vocabulary. A vocabulary model is then introduced, comprised of words containing already acquired letter shapes and connections. Words are chosen based on their meaning and letters composition.

3.2.5 Letter Composition and Connection Model.

We begin by examining the building blocks of the language, i.e., the alphabet letters. The Arabic alphabet includes 28 letters, shown below with the pronunciation of each letter written next to it:

أ (aleph), ب (ba'), ت (ta'), ث (tha'), ج (jeem), ح (ha'), خ (kha'), د (dal), ذ (thal), ر (ra'), ز (zain), س (seen), ش (sheen), ص (sud), ض (dhad), ط (ta'), ظ (tha'), ع (ain), غ (gain), ف (fa'), ق (ghaf), ك (kaf), ل (lam), م (meem), ن (noon), ه (ha), و (wow), ي (ya)

Figure 1 The Arabic alphabet with English transliteration

A careful examination of the forms of these letters reveals that they are basically assembled from nineteen atomic shapes, combined in a variety of ways. These atomic shapes are shown in Figure 2:

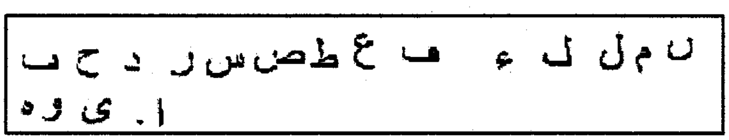

Figure 2 The atomic shapes of the Arabic alphabet

Connection points represent the various ways in which a letter could connect to others in a word. Either it appears at the beginning of the word, i.e. consecutive letters connect to it form the left hand side (Arabic is written right to left). It could be in the middle of the word, i.e., the letter has adjacent letters to the left and right hand sides. Lastly, it could appear at the end of the word, in which case all the letters appear to the right hand side of the letter under consideration. The following figure represents all the letter shapes of all twenty eight Arabic letters when connected at the various connection points in a word.

Standalone Letter	Beginning Connection Shape	Middle Connection Shape	Ending Connection Shape
أ	ـأ	أ	
ب	بـ	ـبـ	ـب
ت	تـ	ـتـ	ـت
ث	ثـ	ـثـ	ـث
ج	جـ	ـجـ	ـج
ح	حـ	ـحـ	ـح
خ	خـ	ـخـ	ـخ
د	د	ـد	
ذ	ذ	ـذ	

ر	ر	ـر	
ز	ز	ـز	
س	سـ	ـسـ	ـس
ش	شـ	ـشـ	ـش
ص	صـ	ـصـ	ـص
ض	ضـ	ـضـ	ـض
ط	ط	ـط	
ظ	ظ	ـظ	
ع	عـ	ـعـ	ـع
غ	غـ	ـغـ	ـغ
ف	فـ	ـفـ	ـف

ق	قـ	ـقـ	ـق
ك	كـ	ـكـ	ـك
ل	لـ	ـلـ	ـل
م	مـ	ـمـ	ـم
ن	نـ	ـنـ	ـن
ه	هـ	ـهـ	ـه
و	و	ـو	
ي	يـ	ـيـ	ـي

Figure 3 Connection shapes of each letter of the Arabic alphabet

The following table extracts the atomic shapes arrived at by visually inspecting the stand alone letter shapes and their three possible connection shapes. We also assigned them symbols and names for use when formally defining the letter shape or connection styles in the future work. Table 1 associates each shape with a symbol.

ا :=S1, alifalone	ل :=S 2, kafalone	ء :=S3, hamza	ڡ :=S4 fakhaf	ع :=S5 ain	ط :=S6 Ta
ص :=S7 sad	س :=S8, seen	ر :=S9 ra’	د :=S10 dal	ح :=S11 ha’	ٮ :=S12, ba’ta’tha’
• :=S13, nukta	ى :=S14, ya’	و :=S15 wow	ه :=S16 ha’	ں :=S1 7, noon	م :=S18, meem
ل :=S19, lam	ـا :=S20, alifjopined	ٮـ :=S2 1, bajoined_be g	ـٮ :=S22 bajoined_en d	ـٮـ :=S23 bajoined_m iddle	ـحـ :=S24, ha’joined_mi ddle
ـح :=S25, ha’joined_e nd	حـ :=S26, ha’joined_b eg	ـحـ :=S27 Ha’joined mid	ـد :=S28, dal_joined_ end	ـر :=S29, ra_joined_e nd	سـ :=S30, seen_joined_ beg
ـسـ :=S31,	ـس :=S32,	صـ := S33,	ـصـ :=S34,	ـص :	ط :=S36,

seen_joined_mid	seen_joined_end	sad_joined_beg	sad_joined_mid	=S35, sad_joined_end	ta'_joined_beg
ـط : =S37 ta'_joined_end	عـ :=S38, ain_joined_beg	ـعـ :=S39, ain_joined_mid	ـع :=S40, ain_joined_end	فـ :=S41 fa_joined_beg	ـفـ :=S42, fa_joined_mid
ـف :=S43, fa_joined_end	كـ :=S44m kaf_joined_beg	ـكـ :=S45, kaf_joined_mid	ـك :=S46, kaf_joined_end	لـ :=47, lam_joined_beg	ـلـ :=48, lam_joined_mid
ـل :=49, lam_joined_end	مـ :=S50, meem_joined_beg	ـمـ :=S51, meem_joined_mid	ـم :=S52, meem_joined_end	ـن :=S53, noon_joined_end	هـ :=S54, ha_joined_beg
ـهـ :=S55, ha_joined_mid	ـه :=S56, ha_joined_end	و :=S57 wow	ـي :=S58 ya_joined_end		

Table 1 Letter connection shapes and associated symbols

In the work to come in our research, letter composition and connection shapes will be captured using two distinct two-dimensional grammars. The first describes standalone letter composition rules while the second describes how each letter connects to others at one of the three possible connection points.

Initially, composition rule constraints must be defined in order to provide a complete grammar defining the entire alphabet. This includes a table visually exposing all potential, relative locations placed around a given atomic letter to compose a letter.

Next is the need to make clear definitions for adjectives describing relative locations of atomic shapes, to be used in the BNF notation defining letter composition rules. More specifically, adjectives such as above, below, inside will be defined and used. Subsequently, a table for BNF grammar to define each letter composition rule in terms of other atomic shapes will be presented.

The usage of the operators above, below and inside used in the BFN grammar below must be further defined. The following list explains these operators.

1) x is above y : y is below x. Alternatively, x is to be placed in the atomic shape location available directly above y's shape location. Visually, the shape above is placed within a picture box five to ten pixels above the one below. (See table 2 below in which 'x' indicates possible positions to place a shape)

2) x is below y: y is above x. Alternatively, x is to be placed in the available box location directly below y's location. Visually, the shape below is placed 5 to ten pixels above the one above. Refer to table 2 below.

3) x is inside y : y is outside x. Alternatively, x is surrounded by y. y is always larger than x. Visually, x is always placed in the picture box placed in the center of the picture box containing y.

4) x ConnectTo y : x is touching y. This means x visually merges onto y via a small horizontal connection.

5) x DoNotConnectTo y : x is not touching y. This means x does not merge onto y via a small horizontal connection.

The following table, Table 2, outlines the location of all possible points of connection from all other atomic shapes to the one under consideration. The exact definition of how each letter is comprised of the atomic shapes will appear in the table to come.

Arabic letter	Location of potential connections to other, adjacent atomic shapes (possible connection locations: above, below, or inside)	Visual representation of possible atomic shapes positions
ا	Above, Below	X ا X
ى	Below	ى XX
•	Above, below	X • X
و	None	و
ه	None	ه

ح	Inside, above	X حX
ں	Above	X ں
م	None	م
ل	None	ل
لـ	Inside	Xلـ
ء	Above, beside	ء X X
س	Above	X XX س
ڡـ	Above	XX ڡـ
ص	Above	X ص
ع	Above	X ع
ط	Above	طX

د	Above	
ٮ	Above, Below	

Table 2 Visual representation of connection shape positioning for all letters

Table 3 explains how each letter and BNF notation will be used to formalize the composition rule for a given letter. The table defines each letter by explaining visually explaining its composition rule, and corresponding BNF grammar applied to the atomic shapes composing it.

Arabic letter	BNF Symbol	Composition Rule	BNF Notation
ا	L1	Place one symbol S13 on top of symbol S1	L1:= <S1>above <S3>
ب	L2	Place one S13 symbols under symbol S12	L2:= <S13>above <S12>
ت	L3	Place two S13 symbols on top of symbol S12	L3:= <S12>above <S13><S13>
ث	L4	Place two S13 symbols on top of symbol S12	L4:= <S12>above <S13><S13><S13>
ج	L5	Place one S13 symbols in the middle of symbol	L5:=<S11>inside <S13>

		S11	
ح	L6	Symbol S11	L6:=<S11>
خ	L7	Place one S13 symbol on top of symbol S11	L7:= <S11>above <S13>
د	L8	S10	L8:=<S10>
ذ	L9	Place one S13 symbol on top of S10	L9:=<S10>above<S13>
ر	L10	S9	L10:=<S9>
ز	L11	Place one S13 symbol on top of S9	L11:= <S9>above<S13>
س	L12	S8	L12:=<S8>
ش	L13	Place three S13 symbols on top of S8	L13:=<S8>above<S13><S13><S13>
ص	L14	S7	L14:=<S7>
ض	L15	Place one S13 symbol on top of S7	L15:= <S7> above<S13>
ط	L16	S6	L16:=<S6>
ظ	L17	Place one S13 symbol on top of S6	L17:= <S6>above <S13>
ع	L18	S5	L18:= <S5>
غ	L19	Place one S13 symbol on top of S5	L19:= <S5>above <S13>
ف	L20	S4	L20:=<S4>above <S13>
ق	L21	Place two S13 symbols on top of S4	L21:= <S4>above <S13><S13>
ك	L22	Place one S3 symbol in the middle of S2	L22:=<S2>inside<S3>
ل	L23	S19	L23:=<S19>
م	L24	S18	L24:=<S18>
ن	L25	Place one S13 symbol in the middle of S17	L25:=<S17>above<S13>
ه	L26	S16	L26:=<S16>

و	L27	S15	L27:= <S15>
ي	L28	Place two S13 symbols below S14	L28:= <S14>below<S13><S13>
ء	L29	S3	L29:=<S3>

Table 3 Standalone Letter shape modeling using BNF

Letter Connection Shape Modeling

Table 4 outlines the three connection shapes of each letter, described in terms of the atomic shapes previously extracted and their corresponding symbols. The fourth column describes how each letter connects at various parts of the word. While some letters attach themselves to adjacent letters in a word, others do not connect from either the left or the right. They remain the same shape on that side of the letter (right or left) regardless of their location in the word.

The following BNF notations are used in the fourth column.

Letter to the left (of the letter under consideration): LL

Letter to the right (of the letter under consideration): RL

The Connect and DoNotConnect operators have already been defined.

Arabic letter	**Letter Connection Shape**	**BNF Symbol**	**BNF Shape Notation**	**BNF Notation Connection Rule**
ا	Beginning: ا	L1B	L1B:= L1:= <S1>above <S3>	L1B:=<L1> NotConnect<LL>
	Middle: ـا	L1M	L1B:= L20	L1M:=<LL>DoNotConnectTo< L1> ConnectTo<RL>
	End: ـا	L1E	L1E:= L20	L1M:= <L1> ConnectTo<RL>
ب	Beginnin	L2B	L2B:= <S59>above <S21>	L2B:=<L2> ConnectTo<LL>

	g: ـب			
	ـبـ	L2M	L2M:= <S59>above <S22>	L2M:=<LL>ConnectTo<L2> ConnectTo<RL>
	ـب	L2E	L2E:= <S59>above <S23>	L2M:= <L2> ConnectTo<RL>
ت	تـ	L3B	L3B:= <S21>above <S13><S13>	L3B:=<L3> ConnectTo<LL>
	ـتـ	L3M	L3M::= <S21>above <S13><S13>	L3M:=<LL>ConnectTo<L3> ConnectTo<RL>
	ـت	L3E	L3E:= <S22>above <S13><S13>	L3E:= <L3> ConnectTo<RL>
ث	ثـ	L4B	L4B:= <S21>above <S13><S13><S13>	L4B:=<L4> ConnectTo<LL>
	ـثـ	L4M	L4M:= <S21>above <S13><S13><S13>	L4M:=<LL>ConnectTo<L4> ConnectTo<RL>
	ـث	L4E	L4E:= <S22>above <S13><S13>><S13>	L4E:= <L4> ConnectTo<RL>
ج	جـ	L5B	L5B:=<S26>below<S 13>	L5B:=<L5> ConnectTo<LL>
	ـجـ	L5M	L5M:= <S24>below<S13>	L5M:=<LL>ConnectTo<L5> ConnectTo<RL>
	ـج	L5E	L5E:= <S25>inside<S13>	L5E:= <L5> ConnectTo<RL>
ح	حـ	L6B	L6B:=<S26>	L6B:=<L6> ConnectTo<LL>
	ـحـ	L6M	L6M:=<S24>	L6M:=<LL>ConnectTo<L6> ConnectTo<RL>
	ـح	L6E	L6E:=<S25>	L6E:= <L6> ConnectTo<RL>
خ	خـ	L7B	L7B:=<S26>above<S 13>	L7B:=<L7> ConnectTo<LL>
	ـخـ	L7M	L7M:= <S24> above <S13>	L7M:=<LL>ConnectTo<L7> ConnectTo<RL>

	ـخ	L7E	L7E:= <S25> above <S13>	L7M:= <L7> ConnectTo<RL>
	د	L8B	L8B:=<S10>	L8B:=<L8>
	ـد	L8M	L8B:=<S28>	L8M:=<LL>DoesNotConnectTo <L8> ConnectTo<RL>
	ـد	L8E	L8E:=<S28>	L8E:= <L8> ConnectTo<RL>
ذ	ذ	L9B	L9B:=<S10>above<S 13>	L9B:=<L9>
	ـذ	L9M	L9B:=<S28>above <S13>	L9M:=<LL>DoesNotConnectTo <L9> ConnectTo<RL>
	ـذ	L9E	L9E:= <S28>above<S13>	L9M:= <L9> ConnectTo<RL>
ر	ر	L10B	L10B:=<S9>	L10B:=<L10>
	ـر	L10M	L10B:=<S29>	L10M:=<LL>DoesNotConnectT o<L10> ConnectTo<RL>
	ـر	L10E	L10E:= <S29>	L10E:= <L10> ConnectTo<RL>
ز	ز	L11B	L11B:=<S9>above<S 13>	L11B:=<L11>
	ـز	L11M	L11B:=<S29>above <S13>	L11M:=<LL>DoesNotConnectT o<L11> ConnectTo<RL>
	ـز	L11E	L11E:= <S29>above<S13>	L11E:= <L11> ConnectTo<RL>
س	سـ	L12B	L12B:=<S30>	L12B:=<L12> ConnectTo<LL>
	ـسـ	L12M	L12M:=<S31>	L12M:=<LL>ConnectTo<L12> ConnectTo<RL>
	ـس	L12E	L12B:=<S32>	L12E:= <L12> ConnectTo<RL>
ش	شـ	L13B	L13B:=<S30>above <S13><S13><S13>	L13B:=<L13> ConnectTo<LL>
	ـشـ	L13M	L13M:=<S31>above <S13><S13><S13>	L13M:=<LL>ConnectTo<L13> ConnectTo<RL>

	ـش	L13E	L13B:=<S32>above <S13>< S13>< S13>	L13E:= <L13> ConnectTo<RL>
ص	صـ	L14B	L14B:=<S33>	L14B:=<L14> ConnectTo<LL>
	ـصـ	L14M	L14B:=<S34>	L14M:=<LL>ConnectTo<L14> ConnectTo<RL>
	ـص	L14E	L14B:=<S35>	L14E:= <L14> ConnectTo<RL>
ض	ضـ	L15B	L15B:=<S33>above <S13>	L15B:=<L15> ConnectTo<LL>
	ـضـ	L15M	L15B:=<S34> above <S13>	L15M:=<LL>ConnectTo<L15> ConnectTo<RL>
	ـض	L15E	L15B:=<S35> above <S13>	L15E:= <L15> ConnectTo<RL>
ط	طـ	L16B	L16B:=<S6>	L16B:=<L15> ConnectTo<LL>
	ـطـ	L16M	L16M:=<S37>	L16M:=<LL>ConnectTo<L15> ConnectTo<RL>
	ـط	L16E	L16E:=<S37>	L16E:= <L15> ConnectTo<RL>
ظ	ظـ	L17B	L17B:=<S6>above <S13>	L17B:=<L16> ConnectTo<LL>
	ـظـ	L17M	L17M:=<S37> above <S13>	L17M:=<LL>ConnectTo<L16> ConnectTo<RL>
	ـظ	L17E	L17E:=<S37> above <S13>	L17E:= <L16> ConnectTo<RL>
ع	عـ	L18B	L18B:= <S38>	L18B:=<L17> ConnectTo<LL>
	ـعـ	L18M	L18M:= <S39>	L18M:=<LL>ConnectTo<L17> ConnectTo<RL>

	ـع	L18E	L18E:= <S40>	L18E:= <L17> ConnectTo<RL>
غ	غـ	L19B	L19B:= <S38>above <S13>	L19B:=<L18> ConnectTo<LL>
	ـغـ	L19M	L19M:= <S39>above <S13>	L19M:=<LL>ConnectTo<L18> ConnectTo<RL>
	ـغ	L19E	L19E:= <S40>above <S13>	L19M:= <L18> ConnectTo<RL>
ف	فـ	L20B	L20B:=<S41>above <S13>	L19B:=<L19> ConnectTo<LL>
	ـفـ	L20M	L20M:=<S42>above <S13>	L20M:=<LL>ConnectTo<L20> ConnectTo<RL>
	ـف	L20E	L20E:=<S43>above <S13>	L20M:= <L20> ConnectTo<RL>
ق	قـ	L21B	L21B:= <S41>above <S13><S13>	L21B:=<L21> ConnectTo<LL>
	ـقـ	L21M	L21M:= <S42>above <S13><S13>	L21M:=<LL>ConnectTo<L21> ConnectTo<RL>
	ـق	L21E	L21M:= <S43>above <S13><S13>	L21E:= <L21> ConnectTo<RL>
ك	كـ	L22B	L22E:=<S44>	L22B:=<L22> ConnectTo<LL>
	ـكـ	L22M	L22M:=<S45>	L22M:=<LL>ConnectTo<L22> ConnectTo<RL>
	ـك	L22E	L22E:=<S46>inside <S3>	L22E:= <L22> ConnectTo<RL>

ل	لـ	L23B	L23B:=<S47>	L23B:=<L23> ConnectTo<LL>
	ـلـ	L23M	L23M:=<S48>	L23M:=<L23>ConnectTo<L21> ConnectTo<RL>
	ـل	L23E	L23E:=<S49>	L23M:= <L23> ConnectTo<RL>
م	مـ	L24B	L24B:=<S50>	L24B:=<L24> ConnectTo<LL>
	ـمـ	L24M	L24M:=<S51>	L24M:=<LL>ConnectTo<L24> ConnectTo<RL>
	ـم	L24E	L24E:=<S52>	L24E:= <L24> ConnectTo<RL>
ن	نـ	L25B	L25B:=<S21>above< S13>	L25B:=<L25> ConnectTo<LL>
	ـنـ	L25M	L25M:=<S23>above< S13>	L25M:=<LL>ConnectTo<L25> ConnectTo<RL>
	ـن	L25E	L25E:=<S53>above< S13>	L25E:= <L25> ConnectTo<RL>
ه	هـ	L26B	L26:=<S16>	L26B:=<L26> ConnectTo<LL>
	ـهـ	L26M		L26M:=<LL>ConnectTo<L26> ConnectTo<RL>
	ـه	L26E		L26M:= <L26> ConnectTo<RL>
و	و	L27B	L27:= <S15>	L27B:=<L27>
	ـو	L27M		L27M:=<LL>DoesNotConnectTo<L27> ConnectTo<RL>
	ـو	L27E		L27E:= <L27> ConnectTo<RL>

ي	يـ	L28B	L28:= <S14>below<S13><S 13>	L28B:=<L28> ConnectTo<LL>
	ـيـ	L28M		L28M:=<LL>ConnectTo<L28> ConnectTo<RL>
	ـي	L28E		L28M:= <L28> ConnectTo<RL>
ء	ء	L29B	L29:=<S3>	L29B:=S3
	ء	L29M		L29M:= S3
	ء	L29E		L29E:= S3

Table 4 Letter connection shape modeling using BNF grammar

Composing the standalone Arabic letters from the atomic shapes is a context independent process, as each standalone letter will appear the same way regardless of what other letters are beside it. Context sensitivity comes into effect when considering the connection shapes for each letter. In this case, connection shapes will depend on the following factors:

1) The letter appears at the end of the word. In this case, it has a possible connection point to another letter from the right hand side.

2) The letter appears at the beginning of the word. In this case, it has a possible connection point to another letter from the left hand side.

3) The letter is to appear at the middle of the word. Then the letter appearing before to the letter under consideration must be taken into account when deciding upon the current letter shape.

3.2.6 Vocabulary Model

The vocabulary model is simply a set of chosen words for interactive learning by the target user group. Research described by the authors of [Hiebert and Kamil, 2005] shows that throughout the school year, students of grade one level learn about 860 words. For reasons of practicality, the work in this thesis will bound the amount of vocabulary to be delivered this grade level. Three criteria must be considered when deciding upon the kind and amount of vocabulary to include.

Firstly, every word must be relevant to the every day life children in the age group under consideration for ease of reference and memorization, as per the phonological awareness study.

Secondly, the words are extracted from the lessons introduced earlier teaching letters and their connection shapes. The words are chosen for reasons of familiarity and reinforcement of relevant content. Vocabulary is extracted from earlier lessons for the purpose of familiarity and reinforcement of previously acquired knowledge. When a student has already seen a word and learned the letters composing it, reintroducing it in a different context, coupled with a meaning facilitates its incorporation into the student's vocabulary.

Thirdly, based on the principles of phonetic similarity discussed in the study reported in [Jong, 2007], 28 words corresponding to the beginning sounds of the 28 Arabic letters will be the set of Arabic vocabulary words to be introduced to the student. This is to reinforce the acquisition of the 28 Arabic letters previously delivered to the student, as per the findings of the phonetic similarity study. Based on these criteria, Table 5 below lists the words to be introduced to the student.

Word In English	Word In Arabic	Meaning	New letter introduced by the	Word Sound

			word	
Arnab	أرنب	Rabbit	أ, ر,ن,	Rabbit.wav
Ballon	بالون	Balloon	ب,ا,ل,و,ن	
Tufaha	تفاحة	Apple	ت,ف,ا,ح,ة	
Thoom	ثوم	Garlic	ث,و,م	
Jaml	جمل	Camel	ج,م,ل	
Hisan	حصان	Horse	ح,ص,ا,ن	
Kharoof	خروف	Sheep	خ,ر,و,ف	
Daraja	دراجة	Bike	د,ر,ا,ج,ة	
Thieb	ذئب	Wolf	ذ,ئ,ب,	
Reesha	ريشة	Feather	ر,ي,ش,ة	
Zarafa	زرافة	Giraffe	ز,ر,ا,ف,ة	
Sayara	سيارة	Car	س,ي,ا, ة	
Shams	شمس	Sun	ش,م, س	
Samgh	صمغ	Glue	ص,م,غ	
Defda'	ضفدع	Frog	ض,ف,د,ع	
Taera	طائرة	Airplane	ط,ا,ئ,ر,ة	

Tharf	ظرف	Envelope	ف,ر,ظ	
Osfoor	عصفور	Bird	ر,و,ف,ص,ع	
Ghazal	غزال	Dear	ل,ا,ز,غ	
Fraise	فريز	Strawberry	ز,ي,ر,ف	
Kunfuth	قنفذ	Porcupine	ذ,ف,ن,ق	
Koob	كوب	Cup	ب,و,ك	
Laimoon	ليمون	Lemon	ن و م ي ل	
Mintad	منطاد	Air Balloon	د,ا,ط,ن,م	
Nakhlah	نخلة	Palm	ة,ل,خ,ن	
Hatif	هاتف	Telephone	ف,ت,ا,ه	
Warda	وردة	Flower	ة,د,ر,و	
Yad	يد	Hand	د,ي	

Table 5 Vocabulary words introduced to the student

The above Table 5 introduces 28 words extracted from an Arabic teaching curriculum. This set of words includes one or more instances of all twenty eight letters of the Arabic language.

Word pronunciation is included as part of the delivery process. Pronouncing a set of letters to phonetically produce a word will also be included as part of the instruction at this level. This is accomplished by sequentially parsing each letter sound composing a word. This is phonetic extraction. After the first letter appears, it is pronounced, and so on for the rest of the letters contained in a word. A word is literally and phonetically composed at the same time. This teaches a student to 'spell out' words and gives the ability to compose new words in the same manner. This skill is applicable to the word composition tasks provided by the software. The visual and audio outputs of a letter within a word occur simultaneously so as to facilitate this process.

The ability to extract all the letter sounds, or phonemes, composing any given word, is termed 'Phonetic Awareness' by the authors of [Chard and Dickson, 1999]. Conversely, phonetic awareness also includes the ability to manipulate phonemes to create a word. Evidently, the vocabulary model of our work builds expects its users to draw on their phonetic awareness abilities in order to succeed in the pronunciation, composition and acquisition of the vocabulary to be delivered. Phonetic awareness is an essential skill for students acquiring reading instruction; it is the mechanism with which students are able to understand internal word structure as discussed in the study reported in [Chard and Dickson, 1999].

As an example, pronunciation of the word 'laimoon" which means "lemon" is proceeds as follows. This word is composed of five letters, ن و م ي ل, in this order. Pronunciation parsing will firstly start at the first letter, ل, and then the letters ي, م, و, and then ن are read out consecutively. Phonetic composition results in pronunciation of the entire word as dictated by its letter sequencing.

In summary, the first step in content creation is to identify unique user characteristics and attributes pertaining to this group. This was kept track of by outlining a user model profiling user abilities, characteristics and usage aptitudes.

Content is authored by examining a given alphabet and extracting modeling principles dictating content delivery and usage. This was achieved by mining the Arabic alphabet for atomic shapes composing all the letters according to a two dimensional grammar describing composition and connection rules.

During the process of authoring letter connection shape content, a complete set of words containing every Arabic letter in all possible position of the word was produced. Letter connection shapes were extracted, modeled, and assigned a BNF grammar for composition.

Creating the vocabulary model drew on words already delivered to the child. These words were chosen to be phonetically associated with each letter of the alphabet. The first sound, phoneme, of every word corresponded to one of the letters of the alphabet. Drawing on the phonetic similarity study reported by the authors of [Jong, 2007], it was concluded that this methodology for developing the user model affirmed a child's knowledge of the letters and introduced new words in a relatable manner.

3.3 Two dimensional system expansion

The following section describes the dimensions of expansion embedded into the content delivery system under discussion.

3.3.1 Vertical Dimension for same language extensions

Vertical expansion of the language delivery system refers to expanding the scope of linguistic content modeling and delivery to broader, more advanced language principles. From a pedagogical perspective, the next linguistic principle to be delivered by any language delivery tool after letter and word creation is simple sentence creation. This would entail modeling language specific figures of speech and grammatical principles dictating sentence creation. At the successive level on the vertical scale of expansion, a two dimensional BNF grammar could conceivably be employed to represent all the possible ways a language's figures of speech could be used to form sentences. The BNF grammar models linguistic syntax rules applied to symbols representing figures of speech. The complexity of the two dimensional BNF grammar describing linguistic grammar would vary depending on the complexity of the linguistic principles sought to be modeled, and the target age group the system is directed to.

Similar to the notion of modeling grammar, we present a model of vocabulary spelling and meaning, expanding what has been put forth in this study. This model lends itself for operation in the following way. Isolating the root of any given word, identifying its meaning and associating similar words and meanings to it would provide a framework of vocabulary acquisition, expanding what has been expressed in this thesis.

Other vertical expansion endeavors could model sound modifiers such as short or long vowels used in conjunction with letters, where relevant in a given language. The modification effect of vowels on letter pronunciation could be modeled to represent a scheme for letters pronunciation within a given word.

Another facet of vertical expansion is to model language phonetics, such as pronunciation rules for the language under consideration. One aspect of this model would entail defining mechanisms of oral sound production. More specifically, a process describing what parts of the mouth, tongue, lips, larynx, each linguistic sound employs for proper pronunciation. This serves to teach students how to correctly pronounce letters and words. Other sound modifiers short or long vowels used in conjunction with letters could be modeled to represent elementary sound modification principles.

At an even higher scheme of language instruction on the vertical scale, a selected set of literature could be extracted from a given teaching curriculum. The core educational concepts to be delivered by this literature could be associated with core literary principles such writing styles, themes, settings, metaphors, similes, parody, and other related concepts such as poetry, rhyme, and rhythm, rhetoric. These associations could then be modeled, giving rise to an intricately designed model of literary work and associated instructional material to be used by language instructors at higher levels of educational instruction.

3.3.2 Horizontal direction cross language extensions

Extending the content modeling theory introduced in this thesis work in a horizontal direction entails applying the basic modeling principles put forth to the instruction of other languages. Some languages can only be instructed in a certain manner. For example, word composition in cursive languages such as Arabic, Urdu or Farsi must be approached differently then would be in English or French. Contrary to non-cursive languages, letters in cursive languages vary in shape depending on position within a word and adjacent letters. Connection shape modeling is most suitable to such languages, and other cursive forms of languages. Other modeling principles such as letter shape modeling, vocabulary introduction, and phonetic association are applicable to any language instruction.

Horizontal expansion schemes applicable to our content delivery system resemble the work of the authors of [Armitage and Bowerman, 2002]. In this research, components containing dedicated CALL technologies are extended for reuse in similar CALL based applications. Similarly, horizontal extendibility refers to lending our language delivery system or resulting application delivery scheme to the instruction of other languages at the same level of instruction. In this work, we used the Arabic language as a case study applying modeling principles devised in our work. Applying core modeling principles atomic shape modeling, vocabulary introduction, and phonetic association could be applied to the instruction of any other formally written or spoken language. The extraction and regrouping of atomic shapes from a given set of letters, according to a two dimensional grammar, is as relevant to other language alphabet sets as it is for Arabic. Similar to this notion of reapplying a two dimensional grammar to other languages for letter modeling, reusability of content was addressed in the study reported in [Petrinjak and Graham, 2004]. In that work, 'learning objects' were designed for the purpose of repeated use within the context of other 'leaning object repositories'. Extending the concepts of the study to our work, the two dimensional grammar is described best as the learning object while new ventures applying the two dimensional grammar to the instruction of other languages most closely resemble the notion of learning object repositories The study explains that the reusability aspect of learning objects this serves to produce a standard for content creation and redistribution for the use of interested parties.

Similarly, modeling letter connection shapes and their combinations to create words is most suitably applicable to instructing word composition in other cursive languages. Words in such languages are complied by combining a given set of letters. Letter shapes within words could possibly take different shapes depending on the relative position within the word. This justifies extending the process of connection shape modeling to such languages.

Considering the age group under consideration, the user model employed to describe his aptitudes and characteristics are applicable to a grade one level student of any language. This confirms the horizontal extendibility of the model devised in this work.

Child learning at the grade one level must operate in the same engaging and stimulating manner regardless of the language being delivered. It must take into consideration grade one level student attributes such as counting, memory, color recognition, and physical coordination abilities in order to customize the delivery process for this age group. The study described in [Zurawsky, 2006] found the one of the most significant factors in acquiring a language is the aptitude of the student to learn a new language. In keeping with this finding, creating an engaging, stimulating delivery process, by way of incorporating a child model customized for the target age group, is seen as likely to increase the student's aptitude for learning Arabic in this way.

Similarly, the evaluation mechanism put forth by this study are applicable to assessment of any linguistic acquisition of a child learning any language. Dragging and dropping atomic shapes onto a work area, and receiving instant, animated and audio feedback works to stimulate students to continuing on in the evaluation exercise. Feedback provided in a child's or parent's voice is deemed interesting to children studying any language. Such an effective evaluation mechanism is applicable to the acquisition process of any language.

The user interface of the resulting software was designed to be simple, intuitive and engaging so as to accommodate the target age group of grade seven students. The association of audio stimulus with visual representations of letters is a common language delivery tool applicable to the instruction of any language. As discussed in the related work section, usage of phonetic similarity to associate letter-sound and letter-word associations is relevant to the process of introducing letters shapes, sounds, related vocabulary, and phonetic extraction in any language.

3.4 Comparison with Related Work

In this section, we compare and relate our research with previously discussed literature. Similar work helps to validate our research methodology and findings. It also presents a framework of comparison and assessment for possible future work.

Research discussing phonetic similarity reported in [Jong, 2007] was considered by our work. This study confirms the benefits of phonetic similarity in delivering preliminary linguistic instruction. It focussed on letter-sound learning by means of associating the sound of a letter with a familiar recognizable word. Their findings show that this enhances the student's ability to acquire letter shape and sound association. As far as our research is concerned, based on this related work, it was determined that best method for introducing letters was to deliver each letter along with a complete set of properties, including a phonetically associated word. Each letter was presented along with a symbol representing it, a sound, and a word which starts with that phoneme. Also, in order to deliver letter connection shapes content, words including a letter in various parts of the word were also included. Further, when creating a set of vocabulary to introduce to the student as part of the vocabulary model, words phonetically associated to each of the 28 Arabic letters were used. This adopted standard helped in delimiting the kind and amount of vocabulary to be introduced to the student of this age group.

Several conclusions could be drawn from this research discussed in [Jong, 2007] and its adaptation into our thesis work. Considering the multitude of methods possible for introducing a set of alphabet letters to a student, a systematic method proven by experimental results needed to be incorporated. For this reason this method was incorporated to introduce the letters of the Arabic alphabet. Another facet of similarity between our research efforts and the results collected in the study reported in [Jong, 2007] is the assumption that children of this age group are able to extract phonemes after hearing a word. Without this assumption, using the concept of phonetic similarity to reaffirm alphabet knowledge is neither feasible nor effective. Further, the content delivery approach adopted by our research resembles that of the related work in that they both deliver alphabetic instruction in a manner firmed on widely accepted, prevalent and proven teaching strategies, such as knowledge repetition, familiarity of words, association of concepts and incorporation of graphical and audio delivery tools into the learning process.

One obvious difference between this study and ours is that we apply phonetic similarity to the Arabic language whereas the study focuses on the English language as a case study. Another difference is that that there was no experiment to demonstrate the effectiveness of phonetic similarity in introducing Arabic letters in our study. The results of the research discussed in [Jong, 2007] were the basis for us to use this approach. We also extended the sound-word association to words in which the letter under consideration was not positioned at the beginning of the word, but in other positions within the word. This works on the basis that not only can a student of this age group extract phonemes, but the sounds of other letters within a word, and associate it with a symbol representing that letter.

The study on handwritten character recognition discussed by the author of [Leigh, 2005] puts forth a methodology for recognizing handwritten characters, using a segmentation scheme applied to internally stored character models. Input characters are decomposed into segments and the degree of conformity to one of predefined character segments is identified and on this basis, a hand written character is recognized.

This study reported in [Leigh, 2005] was incorporated into this thesis. The notion of partitioning alphabet letters into atomic shapes is synonymous to the concept of dividing a character into segments which composes character models according to a segmentation schema. The segmentation scheme which must be interpreted in order to arrive at a correct character model, is also synonymous to the two dimensional grammar defining the composition rule for each letter. In the same way that segmentation schemes must be interpreted in order to identify the character model under consideration, the two dimensional grammar pertaining to each letter must be processed in order to arrive at the letter's shape given the basic atomic shapes as input. Conversely, creating a letter by placing a number of atomic shapes in place relative to each other is a verifiable process, accomplished by comparing atomic shape locations against the two dimensional grammar of each letter; which describes its composition rules. The two dimensional grammar is parsed and the kind and position of each atomic shape involved in creating the letter is evaluated for correctness.

One facet of difference between that study and ours is the fact that it stipulates a minimum stroke length to be considered as part of the character input to be deciphered. In our study, users are presented with a set of preexisting atomic shapes with standard sizes, and the student is able to choose the atomic shapes he/she would like to use in order to create a given letter. Another striking difference is that the user in our work does not create the shapes he/she will use to compose a letter but rather select them from a menu provided through the interface.

Unlike the methodology of proposed by the author of [Leigh, 2005], atomic shape combinations in our work are not evaluated based on the alphabet letter they are to create. Quite the contrary, after being prompted to create a given letter, the accuracy of which atomic shapes a student selected to complete his task is then evaluated. This is in contrast to scoring each handwritten character stroke on the degree of conformity to a certain character segment, as done in the study detailed in [Leigh, 2005].

There is no atomic shape cashing in our work as there is segment shape cashing for the creation of the next character to be handwritten. Instead, our efforts start with no assumptions about user choices of atomic shapes. This enhances the evaluation process and reinforces student knowledge of letter shapes.

To conclude, it is our conjecture that the basic methodologies used for reconstruction of a given letter, as used in our study or the decoding of handwritten segments done in the study under consideration; both rely on the same core principles. These principles consider using a predefined scheme of character recognition based on extraction of sub-shapes composing it. For reasons of practicality and feasibility, a pen device was not the input method of choice for the age group we are considering in our study, as such an input mechanism is too costly to incorporate and implement. Had this been the input method of choice accepted by our resulting application, then the exact same methodology of decoding student input would have been implemented.

The study reported in [Brooks et al., 2005] on learning object content management systems is relevant to ours in that it addresses similar learning content management system issues. It discusses content authoring and delivery issues, for which it puts forth solutions. The engines of delivery are an object sequencing environment, a content delivery tool, and an assessment application for quality of delivery. These tools operate together to deliver content packages as per predefined manifest files. Learner modeling is used as a tool of attending to user delivery needs and preferences.

The most notable similarity of our work and this study is the notion of 'content packages' described by 'manifest files' defining the package metadata. Content packages are analogous to the concept of standalone letter reconstruction from atomic shapes discussed in our work, and the concept of a manifest file describing metadata relationships is analogous to the BNF of two dimensional grammars we used to describe atomic shape associations required to recreate a given letter.

The concept of simple sequencing discussed in this related area of research is evident in the work put forth in our study. This is manifested by the fact each of the 5 main sections of content delivery and evaluation rely on the previous instruction level. For example, before a student is able to complete the letter creation section, he/she must have gone through lessons for introducing the 28 Arabic letters in order to be able to identify the shape and sound of each letter and successfully completed the letter recognition exercise.

Further, before the student is able to complete the word creation section, he/she must have been delivered and properly completed creating a letter exercise. Pedagogical sequencing implemented by our work mandates the same effect as is resultant from simple sequencing. However, since our work allows students to omit content areas with which he/she is already familiar, our content delivery sequencing strategy is not as unidirectional as simple sequencing is. Students are enabled to explore any section of the delivery application based on their learning needs. This is one facet of difference between our work and that of the related research.

The notion of learner modeling is introduced, specifically as it relates to content adaptation. Similarly, our work uses a simple user model describing user preferences relevant for content delivery and evaluation scoring. Taking into consideration the age group of the target users, our proposed delivery process was designed to be engaging in nature, expressive with positive or negative feedback in the form of audio and visual aids, depending on performance. One difference between our work and related research is that there is little or no content adaptation based on user performance. Considering the limited amount of content to be authored and delivered and the target age group, delivery adaptation of this limited amount of content does not contribute much to our work. There are only 5 main interfaces available to the student. Adaptive browsing is left to the preference of the user, rather than being an automatic response to user actions. This is another difference between our work and the research under consideration. However, if we expanded to content to higher levels of linguistic instructions, i.e., higher than grade one level, then the user model would naturally be more complex in order to describe a more complex set of user preferences and behaviors. Incorporating user progress through the increased amount of linguistic content, keeping track of user evaluation results, and integrating a sequencing procedure based on the evaluation results would also be included in the user model. This would naturally require the incorporation of adaptive content delivery technologies.

Several conclusions could be drawn from our study and comparison to related work. One such conclusion is that because the learning management system crafted in the study caters to the needs of an older, more sophisticated audience of users, its delivery engine is more complicated due to the notion of adaptive content delivery.

The user model devised in our work is simplistic in that it merely defines characteristics and preferences specific to users of this age group rather than a detailed user model created per user of the system. This is because computer users of this age group are limited in their capabilities in interacting with any given software; the complexity of their actions need not be remembered with a user model. This is found to be more in keeping with the goals of this research work, considering our initial objectives and motivations.

As far as similarities between our research and related work, both approaches naturally incorporate common learning content management system principles such as content encapsulation, content description tools, and a delivery engine accommodating its perspective set of users.

The author of [Warschauer, 1996] discusses the evolution of CALL over the past 30 years and provides an overview of the most prominent concepts and techniques influencing computer aided language learning. This evolution process identifies integrative CALL as the most recent phase of development. It builds upon concepts introduced in earlier phases, such as *computer as tutor* and *computer as a stimulus*. It adds a collection of multimedia based stimulus to be delivered to the user at run time and addresses pedagogical and technological issues relevant to designing computer based language learning applications.

Reviewing computer assisted language learning, it became evident that that some concepts relevant to communicative and behaviorist CALL theories such as *computer as tutor* and *computer as stimulus* are also incorporated into our design. Implementation of *computer as tutor* concept is manifested as the language teaching tool stands to correct the student upon mistakes and congratulates him when correct input is received from him. Implementing the *computer as stimulus* model is apparent in the repeated feedback, taking the form of audio and visual stimulus delivered to the user when interacting with the system. This entire notion is the basis for creating an engaging tool for the age group under consideration.

Having noted the similarities between our research efforts and the first two phases of CALL theories, we can conclude that our study most closely resembles integrative CALL based application in that textual, graphical, animated and audio input is used in the delivery and feedback process relayed to the user of our system. There are however, no hypermedia links available to the end user of our resulting software. This is essentially because there are five units of content delivery; providing hypermedia browsing abilities does not add any valuable functionality, especially considering the age group the delivery process caters to. As with integrative CALL applications, reading, writing, and listening are all possible at the same time so as to maximize the learning experience of the user.

Addressing the issue of authoring linguistic material to be delivered by the application, an existing Arabic teaching curriculum was used as a basis for extracting relevant content for grade one language curriculum to be delivered with a computer based application. This implementation decision ensures pedagogical accuracy and sequencing, while creation of the delivery tool was based on grade one level user model and content models firmed in CALL theory. This strategy ensures to strike a balance between CALL principles and pedagogical accuracy. This is in contrast to the operation of most integrative CALL applications, where pedagogical and technological issues are resolved with AI technologies.

To conclude a review of this literature, as compared with our efforts, it is evident that most prevalent aspects of integrative CALL based applications was incorporated into our work, while omitting aspects less relevant to the age group under consideration. Audio, visual, animated stimulus were an integral part of the application while reading, listening, letter and word composition exercises were delivered simultaneously as the user progressed through the application.

Chapter 4 System Design, Testing and Evaluation

The personal software process followed in this thesis is aimed at organizing and improving personal efforts of developers and software engineers as confirmed in the study described in [Silberberg, 1998]. The basis of this software process is to embed reviews at every cornerstone of the development cycle of any given software project. The expected behavior of the software is outlined, pseudo code implementing this behavior is provided, and finally, these high level objectives are expressed in the programming language used.

When design of the behavior is completed, analyzed and reviewed, the code is compiled and run. Any code errors call for a root cause analysis. This is based on the philosophy that detailed analysis of the code leading to detection and resolution of design time errors leads to better code. Research suggests that there is a two to three fold increase in quality as a result of applying the PSP to development as reported by the authors of [Humphry and Khajenoori, 1995]. Process data will be used to judge the quality of software developed. Similar research discussed in the study reported in [Fergusen et al., 1997] authenticates PSP process effectiveness in terms of delivery time and quality of software to be applied in within the organization of three software development groups.

The personal software process development consists of five stages. These stages will be defined and followed in the development process of a software tool in this thesis for teaching grade one Arabic language, called AlifBaTa Teacher.

The first stage is labeled PSP0 as referred to in the study outlined in [Silberberg, 1998]. At this point, performance baselines are set, reporting formats are created, and design, coding and testing objectives are outlined. In the second stage, PSP1, size, resource, task, and schedule plans are made, and a testing report is provided as described in the study reported in [Silberberg, 1998]. PSP2 is a consecutive stage intended to initiate review techniques to resolve the defects detected in the previous stage of the development as described in the study detailed in [Silberberg, 1998]. This is accomplished by creating a tailored review check list based on the defects found in PSP1 for the purposes of increased quality assessment.

The following section discusses details of each phase and its application into our software development process.

4.1 Development Methodology

The PSP model was used in order to develop a language tool intended to teach grade one students preliminary Arabic. In fulfillment of this first phase of development PSP0, the first step involves deciding upon a specified set of tasks which a child of that age is to be able to accomplish. The first concern at this stage of learning is to introduce the 28 Arabic letters. This aspect of the application introduced the standalone letter by itself along with three shapes depicting what the letter looks like at three possible connection points of a word. Words were chosen which include the letter at the three possible connection points of a word, beginning, middle, and end. This process involved collecting relevant images of the chosen words and creating audio files producing letters and words sounds.

The second task was to test the student's letter recognition abilities after being introduced to the entire alphabet. The student is then prompted to recognize a letter among four others chosen and placed at random. Instant feedback relayed after the student makes his choice.

The third step was to design a method for testing a student's letter composition ability. To accommodate the fact that handwritten input is harder to validate, nineteen atomic shapes which compose the entire alphabet according to a predefined two dimensional grammar were composed by examining the alphabet for similar sub-shapes. These shapes are shown to the student using an appropriately designed interface. The student is then verbally asked to compose any given letter, and using drag and drop skills, the student then places the atomic shapes in predefined locations and clicks on a 'Done' button. Verification of the student input is then performed. Animated graphical and audio segments indicating success or failure are then displayed to the child, using recordings from another child or parent. The audio stimulus has the potential for personalization for each student, so as to include his or her parent's prerecorded voice. However, if no parental recordings are provided, the default audio plays a child's voice. Upon composing a letter shape corresponding to the letter under consideration, the student is rewarded with positive graphical and audio stimuli. The recording is heard congratulating and encouraging the student. Upon an invalid response, the student receives negative stimuli in the form of a sad graphical face and the recording indicating he/she or she must try a little harder to successfully complete the exercise.

Both the recorded and graphical feedback differs on every attempt, as they are chosen randomly from a set of pre-defined feedback repository. This was incorporated in order to add an element of surprise to the delivery process and keep the student engaged for new, stimulating feedbacks.

The fourth aspect of the application tests the child's word composition ability acquired as a result of progressing through the section introducing all the 28 letters and their associated words showing each letter at three different connection points, when possible.
A child is asked to insert a missing letter within a word, and the space onto which to drag and drop the correct letter is visible to the student. This step is intended to be a prelude to prompting the student to spell out the entire word.
Once a certain letter is clicked, a menu of all possible connection shapes associated with a letter is displayed to the student. Not only must the student place a letter in the correct letter location within a word, he/she or she must also choose the correct connection shape based on the location currently under consideration and other adjacent letters which may modify a letter's connection shape, as per its two dimensional grammars. Feedback is provided upon every drag and drop operation of a single letter. Once completed the entire word, the student then clicks on a 'Done' button which then provides appropriate audio and graphical feedback regarding the composition of the entire word.
The fifth task prompts the student to proceed to another interface matching the 'insert the missing letter' interface, at which point he/she is prompted to spell out the entire word.
As with the previous interface, feedback is provided instantly one the student clicks on the 'Done' button.
The fourth and fifth tasks described in this section illustrate the 'segmentation activities' described by the authors of [Chard and Dickson, 1999] for assessing phonological awareness of a child. In each of these tasks, students are required to phonologically 'segment' a word into its founding phonemes in order to arrive at its correct composition in terms of letters and complete the task successfully.

4.2 Task Plans and Schedule

PSP1 is a phase designed to define the task and schedule plans. A set of tasks to be accomplished will be defined and then a table setting a schedule for completion of these tasks will be added. This entails the schedule plan.

A test report section will be performed on a child A of age 5 years old, a second on a six year old child B, third on Child C of age 6 years old, fourth on child D age 6 years old, fifth on child E aged 5 years old, a sixth on child F aged 5 years old and a seventh child G aged 5 years old.

4.2.1 Task Plan

The following is the task plan set for this software project.

1) Task One: Compose letter instructional material

This includes the following steps,

1) Develop an interface to deliver Arabic alphabet instruction
2) Collect relevant authored material related to each letter. Create a soft copy of this material to be incorporated into the software as graphical representations.
3) Create recordings which relate to the letter
    a. Letter sounds
    b. Three words containing the letter at various parts of the word
4) Incorporate graphical and audio files into the interface delivering Arabic letters content

The following is a snapshot of the software interface implementing this task

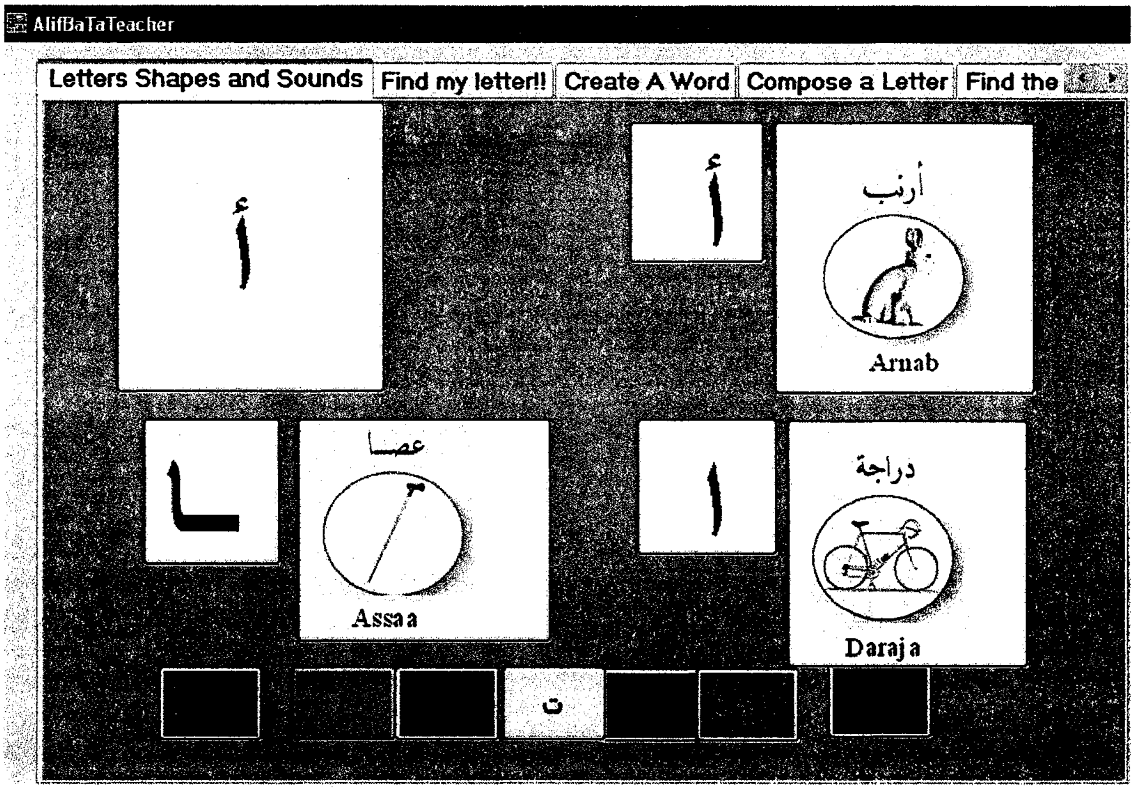

Figure 4 Interface implementing letter instructional material

2) Task two: Implement letter recognition and isolation task

1) Develop an interface to test the students' ability to recognize letters, based on knowledge of letter sound and connection shapes acquired in the previous task.

2) Present a student with a drop down box from which he/she can choose the letter to recognize.

3) Create a subroutine which randomly selects 4 other letters for the student to choose from when recognizing the letter under consideration, and place them in random locations within 5 possible letter locations (with the fifth location occupied with the current letter to be recognized by the student)

4) Personalize the verification process of student input by importing any available prerecorded audio clips of each student's parent positive recordings for satisfactory performance or negative ones for repeated or major errors upon dragging and dropping a letter.
5) Create a feedback randomization procedure to add an element of surprise to the feedback a student receives.

The following is a snapshot of the software interface implementing this task

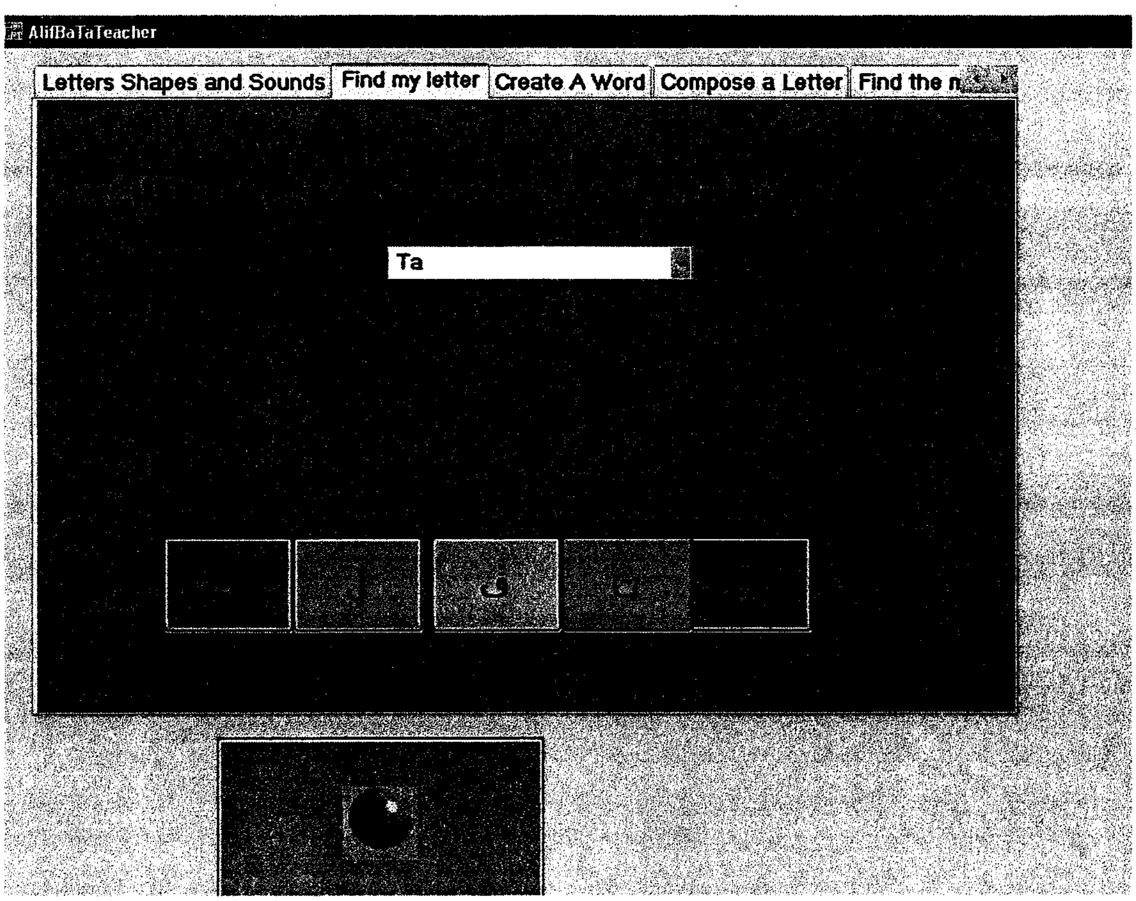

Figure 5 Interface implementing letter recognition and isolation task

3) Task three: Implement letter composition tasks

1) Develop an interface to deliver letter composition tasks

2) Create and display all 19 atomic shapes on the screen and notify the student that he/she can select any one of these shapes to create a letter when prompted
3) Prepare a set of recordings asking the student to compose a given word from the list above. Present a student with a drop down box from which he/she can choose the letter to compose.
4) Create an internal verification mechanism which can automatically verify the student's selected combination of atomic shapes to create a given letter. The verification process is based on a two dimensional grammar previously defined for each letter.
5) Personalize the verification process of student input by importing any available prerecorded audio clips of each student's parent positive recordings for satisfactory performance or negative ones for repeated or major errors. Verification is presented to the student upon each drag and drop operation of an atomic shape.
6) Create a feedback randomization procedure to add an element of surprise to the feedback a student receives.
7) Once the 'Done' button is clicked, verify student choice of atomic shapes and once again, present the randomized feedback to the student.

The following is a snapshot of the software interface implementing this task

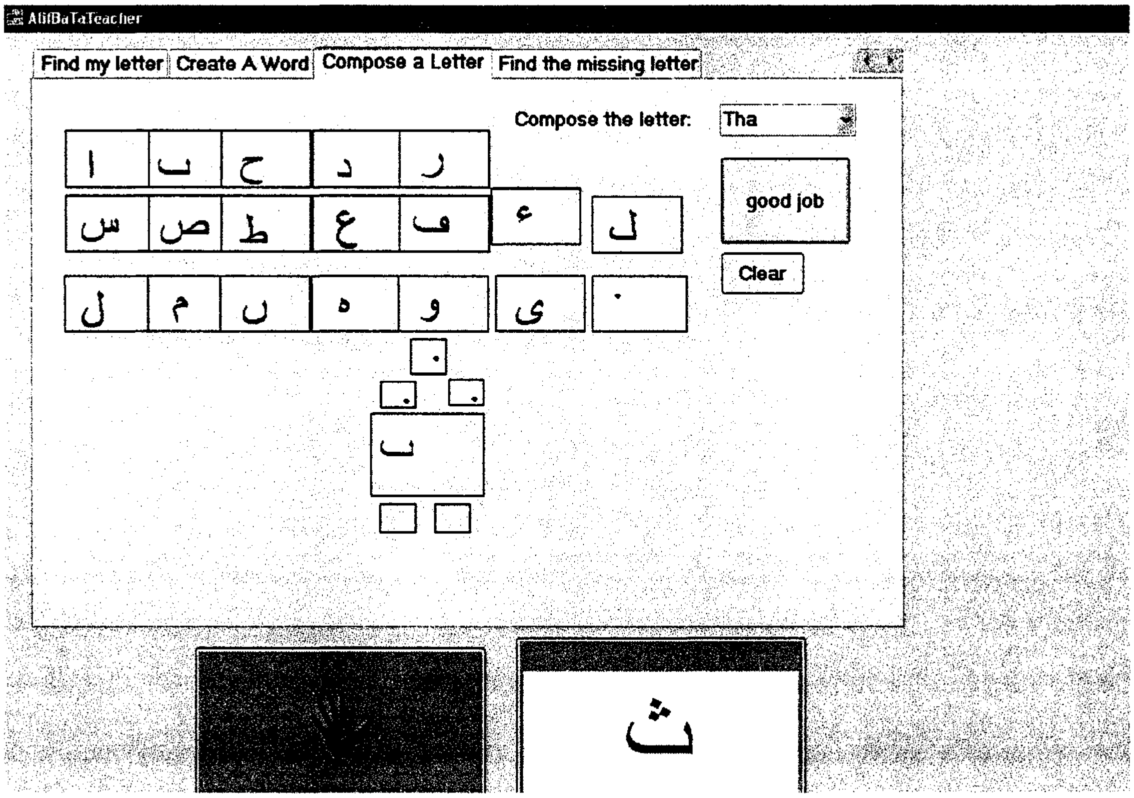

Figure 6 Interface implementing letter composition tasks

4) Task four: Implement letter insertion tasks

1) Compose a list of words to test the student's letter insertion composition abilities (a set of the words learned in task one).

2) Prepare a set of recordings asking the student to compose a given word from the list above. Present a student with a drop down box from which he/she can choose the letter to compose. Present the student with an image of the word into which he/she is to insert a letter along with the English transliteration of the word to facilitate pronunciation and subsequent phonetic deciphering of the word required for the exercise.

3) Present the student with a 'work area', a place to which he/she can drag and drop letters from a menu in order to insert a letter within a word. Each letter of

a word has a box assigned for it within the work area. All of the letters of the word are visible except one chosen at random.

4) Present a menu of all letters to the student
5) Once a student clicks on one of the letters presented in the menu, give him the ability to select one of its connection shapes, drag it to one of the boxes composing a word. This is labeled as the student's work area.
6) Personalize the verification process of student input by importing any available prerecorded audio clips of each student's parent positive recordings for satisfactory performance or negative ones for repeated or major errors upon dragging and dropping a letter. Present this verification process upon each drag and drop operation when composing a word.
7) Create a feedback randomization procedure to add an element of surprise to the feedback a student receives.

The following is a snapshot of the software interface implementing this task

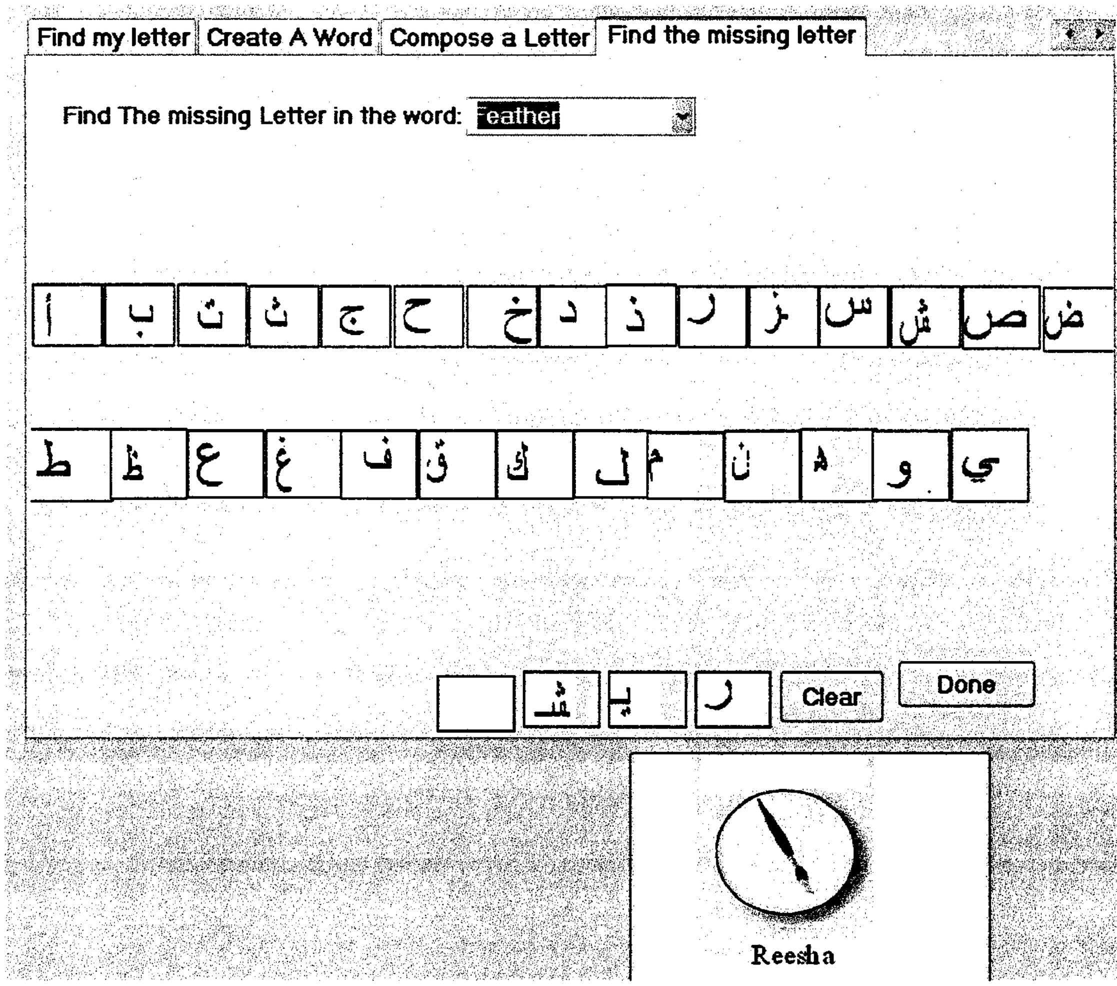

Figure 7 Interface implementing letter insertion within a word

5) Task five: Implement word composition tasks

1) Compose a list of words to test the student's word composition abilities (a set of the words learned in task one).

2) Prepare a set of recordings asking the student to compose a given word from the list above. Present a student with a drop down box from which he/she can choose the letter to compose. Present the student with an image of the word into which he/she is to insert a letter along with the English transliteration of the word to facilitate pronunciation and subsequent phonetic deciphering of

the word required for the exercise.

3) Present the student with a 'work area', a place to which he/she can drag and drop letters from a menu in order to compose a word. Each letter of a word has a box assigned for it within the work area.
4) Present a menu of all letters to the student
5) Once a student clicks on one of the letters presented in the menu, he is given the ability to select one of its connection shapes, drag it to one of the boxes composing a word. This is labeled as the student's work area.
6) Allow the student to repeat this process for all letters composing a word.
7) Personalize the verification process of student input by importing any available prerecorded audio clips of each student's parent positive recordings for satisfactory performance or negative ones for repeated or major errors upon dragging and dropping a letter. Provide this verification process upon each drag and drop operation when composing a word.
8) Create a feedback randomization procedure to add an element of surprise to the feedback a student receives.
9) Present a 'Done' button to be clicked upon completion of the word.
10) Once the 'Done' button is clicked, verify student choice of letters and connection shapes and once again, present the randomized feedback to the student.

The following is a snapshot of the software interface implementing this task

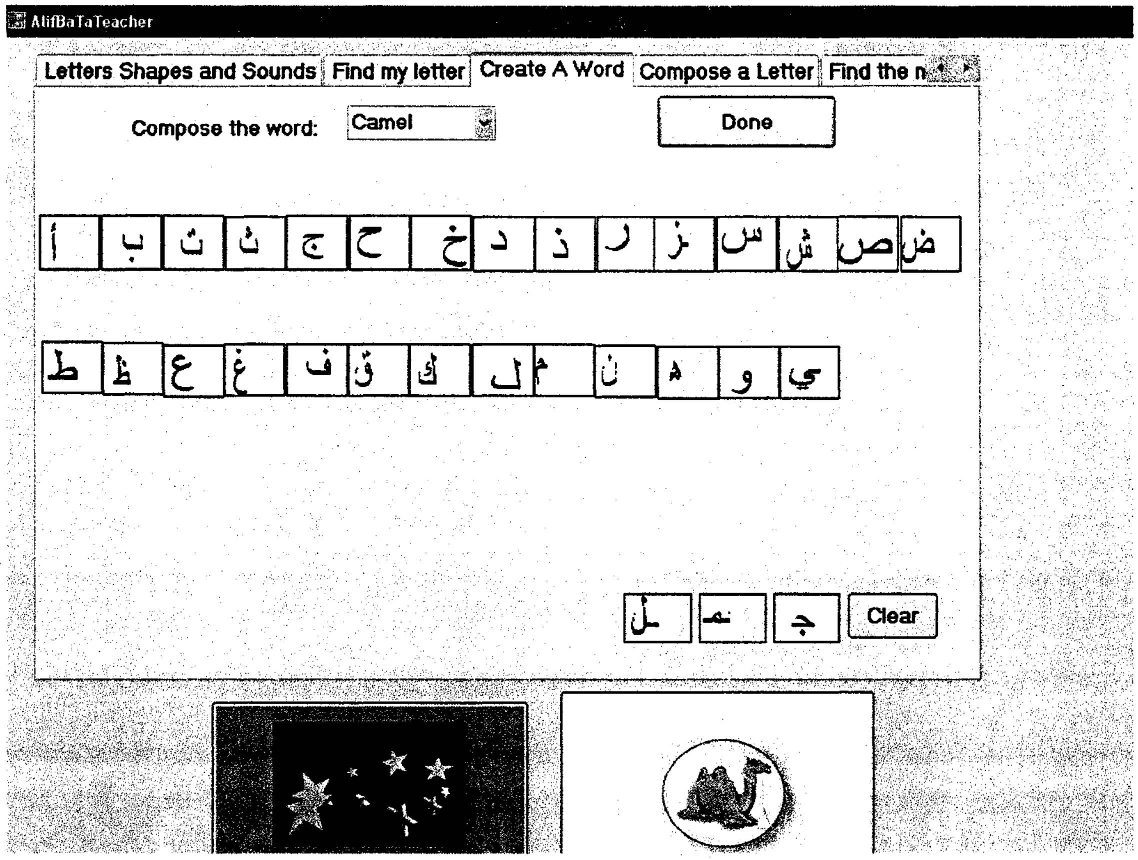

Figure 8 Interface implementing word composition tasks

6) Task six: Test Report Generation/Evaluation

The test report generation process produces a report detailing the interaction of the student with the software system. The student uses the software for several minutes on a daily basis over a period spanning one to two weeks. This is because content acquisition is a gradual process taking place over a period of time and the low attention span of the test audience.

This test report generates data representing successful completion of tasks. It also produces a diary of usage, and from this diary, the interaction of student usage and responses are examined for insight and revelation into the effectiveness of the software.

Student performance in the letter and word recognition and composition tasks evidently reflects on the analysis and evaluation of the software. During the testing process, each student was asked to attempt one or more of each of the 4 main evaluation tasks offered by the application. Each task was categorized into one of the four main categories depending on the nature of the language skill the student is to apply for successful completion. In the 'Find My Letter' category, a student is prompted to draw on his/her letter recognition and memory skills acquired from the 'Letters Shapes and Sounds' section. To complete this task successfully, a student must also exclude irrelevant, distracting content from his /her letter selection process. In the 'Compose a Letter' interface, each task requires the student to recognize a given letter, recognize its atomic shapes, and consequently apply a designated letter's composition grammar when composing it. In the 'Find the Missing Letter' interface, students must perform phonetic disassembly of the designated word and realize which letter it is missing. The student must also identify the connection shape of the missing letter based relative location amongst other letters within the word. In the 'Create a Word' interface, not only must a student apply the same skills as required by the 'Find the Missing Letter' tasks, but he/she must also repeat the missing letter recognition and insertion process to all letters composing a word. This adds an increased level of sophistication to the student's word composition skills.

Task success data collected based on successful completion of tasks belonging to categories and serves as quantitative measurements of overall software quality as each student progresses through his/her interaction with the software. Having predetermined that each student must perform one of each of the main evaluation categories offered by the application, it must be noted that some students performed more tasks than others, overall and per category. This factor was dependant on the student's preferences for the amount and category of tasks to attempt.

Qualitative measures of software quality are depicted by a student's aptitude, attitudes and reactions during his/her interaction with the software. The more positive the student reaction is to using the software the stronger the indication that this is a useful tool of language content delivery. Verbal responses and recommendations about the functioning and feedback mechanism of the application are also taken into consideration. While this report collects student reaction to using the software it does not perform a full usability test. Usability testing involves a different testing methodology not included in the scope of our thesis work.

Both quantitative measurements of task completion success and qualitative physical and verbal observations recorded during student interaction with the software shall be used to judge the software application and underlying content delivery methodology.

Having identified quantitative and qualitative testing metrics for software usage as described previously, it must be noted that several factors possibly contribute to the amount, kind and results of the testing. The time of the day, duration of time spent using the tool, distraction factors and aptitude of the student to learn at the time of testing all contribute to the set of test results. Further, the amount of exposure to the learning material prior to the testing process also yields great affects on the test results.

It must be noted that the evaluation process embedded in our tool provides a guided testing environment. A guided test leads the student during the evaluation sessions through its suggestive nature. For example, when composing letters, locations for dragging and dropping of atomic shapes are limited to certain positions available on a canvas. These locations represent all possible correct shape positions so as to exclude the possibility that a student places a shape on a completely wrong location relative to his work area. This also serves to teach the student about relative locations of atomic shapes composing any letter. Similarly, when composing a word, a number of boxes equal to the number of letters in a word are displayed to the student. This suggests the number of letters, and corresponding letter sounds to spell out when composing the word. English transliterations of relevant words facilitate word composition tasks by helping the student phonetically decipher any given word and relate sounds with Arabic letters.

The following table summarizes the test results report generated from testing the software used by seven children A to G.

Child	**Test results**
Child A results	In the 'Create a Letter' section, child A was presented with all the atomic shapes. She was then asked to create the letter أ (*alif*). She recognized the atomic shapes needed to create the letter *alif* were ا (*alifalone*) and ء (*hamza*). She recognized that ء (*hamza*) must go on top of ا (*alifalone*).
	In the 'Create a Letter' section, child A was asked to compose the letter, ب (ba'). She recognized that the atomic shapes needed to create this letter were

	ٮـ (*ba'ta'tha'*) and • (*nukta*). She first said that • (*nukta*) must go on top of ٮـ (*ba'ta'tha'*). Upon scorning for incorrect response, she then corrected her self and said that ٮـ (*ba'ta'tha'*) must go on top instead. She then said that a letter looking like ـنـ resembled the letter ن (*noon*). She seemed to be drawing on her knowledge of the composition rule of another letter resembling the current one.
	In the 'Create a Letter' section, child A was asked to create the letter ش (*Sheen*). She recognized the atomic shapes needed to create this letter are س (*seen*) and three • (*nukta*) appearing on top of س in a triangle shape.
	Child A looked at the interface showing the letter ا, and a picture of a rabbit beside it, In Arabic أرنب (*Arnab*), and the letter أ (*alif*), is the first letter of that word. Child A recognized the association and said أ (*alif*) is the first letter of the word أرنب (*Arnab*). She also recognized the middle shape of the letter أ (*alif*) in the word دراجة (*Daraja*).
	In the 'Create a Word' section, child A was prompted to create the word شمس (*shams*), and was told that this is a three letter word as displayed by number of boxes on to which she is to drag and drop letters. She was told that the first letter of the word was ش (*sheen*). She was asked to choose the correct

	connection shape for ش (*sheen*) at the beginning of the word. She picked the right one. She was then told the second letter was going to be م (*meem*). She properly chose the middle connection shape for the letter م (*meem*). She was then told the last letter was going to be س (*seen*). She chose the ending connection letter shape for the letter seen. She mentioned that seeing all possible connection shapes in front of her, and knowing which connection shape she was to look for helped her choose the right shape per letter. When asked how she knew which connection style to look for she mentioned she figured that out by the position of the boxes making up the word she was currently working on.
	Child A was asked to create the letter ث (tha'). She successfully identified the bottom atomic shape, ـبـ *(ba'ta'tha')*, and recognized that three dots, • (*nukta*), need to be on top. She made the association that he/she letter ث (*tha'*)has three dot shapes, • (*nukta*), forming a pyramid, just like the letter ش (*sheen*).
	Upon request, child A remembered three words associated with the letter ت (*Ta*), and was able to recognize that the word apple (*tufaha*) showed the letter ت (*Ta*), at the beginning of the word, the word هاتف (*hattif*) showed ت (*Ta*), in the middle of the word, and سيارة (*sayara*) showed ت (*Ta*), at the end of the word.
	Upon request, child A could recognize in the words look at the letter ج (*geem*)

	at different locations of the three associated words. This is based on the pictures to the left hand side of each word showing letter shape at a specified position.
	Child A made the observation that the atomic shape ٮ (*ba'ta'tha*) was common to three letters, ب, ت, and ث. When prompted for more atomic shape recognition among other letters, she pointed out that the atomic shape ح was common to the letters ح, ج and خ.
	Upon request, child A did not at first recognize the middle shape for gain, غ (*gain*), she needed help but when asked for the letter ع(*ain*), she pointed it out right away due to the similar core atomic shape used.
	Child A was asked to compose the letter at ت (*Ta'*). She forgot where the dots are supposed to go. She referred to the letters and shapes section to remember, and then realized two 'dot' atomic shapes need to on top.
	Child A noted that the letter ج(*geem*) was the only one with the dot inside of the three shapes using the atomic shape ح (*Ha'*). They are the letters ج, ح, and خ. The only other letter with an atomic shape in side was ك (*Kaf*). She seemed to be starting to be to make comparisons of letter shapes based on the atomic shapes displayed.
	After about 1 hour from using the Arabic teaching tool and learning three words containing the letter ح (*Ha'*), child A was asked to mention the three words containing the letter at various parts of the word. She relayed the same

	three words she learned through the application.
	In the 'Find My Letter' interface, Child A chose to recognize the same letters she composed, namely the letters ت (*Ta'*), ث (tha'), ش (*Sheen*), ب (ba') and أ (*alif*).
	In the 'Insert the Missing Letter' interface, the student completed 2 letter insertion tasks properly, for the word شطيرة (*shateera*), in which the letter ش (*Sheen*) was inserted and the word زرافة (*zarafah*) in which the letter ف (*fa'*) was inserted.
Child B results	Child B was able to compose correctly 4 out of the 5 words when asked to in the 'Compose a Word' section. When needed, Child B referred to the section introducing the 28 letters to remember the spelling of the prompted words.
	Child B was observed to say out the English equivalents of the words, Rabbit (*Arnab)*, Apple (*Tuffaha)*, Box (*Sondook*). This helped to reassure the testers he was internalizing the words and the meanings delivered to the user.
	Child B was able to quickly learn using the spelling section to spell out the words, quickly learning the way to display the menu of all letter connection shapes.
	Child B was engaged in the process, and suggested that he would like to continue the entirety of his Arabic education on supplemented by a similar application.
	Child B was able to group similarly formed letters and outlined the following

	letter group: a) ب (*Ba'*), ت (*Ta'*) ث (*Tha'*) b) ج (*geem*) ح (*Ha'*), خ (*Kha'*) c) س (*Seen*)and ش(*Sheen*) d) ع (*ain*) and غ (*gain*)
	Child B was asked to provide words starting with the following letters after completing the letter introduction section. He was able to provide the word يد (*Yad)* for the letter ي (*Ya*) hand, ثوم (*Thoom*) garlic, for the letter ث (*Tha'*), دراجة (*daraja*) bike, for the letter د (*dal*), and the word ليمون (*laimoon*) lemon, for the letter ل (*lam*).
	Child B expressed a very positive visual response when congratulated with positive animations upon correct performance on any given task. He was apprehensive about receiving negative feedback upon invalid performance and therefore took more time to resolve what was asked of him.
	When asked about his ability to use a mouse and a keyboard to access the application, Child B expressed complete confidence in using this hardware as he has had prior experience playing child appropriate games online.
	When asked about his disposition about the appearance of the atomic shapes, he said he was content about using the atomic shapes to create letters, mentioning that their very shape suggested the letters they could be used to compose. For example, Child B mentioned that the shape س reminded him of

	the letters س (seen) and ش (*sheen*).
	Child B displayed excitement that the content of this application resembled prior Arabic instruction received at home and at his Saturday Arabic school. He mentioned he preferred the interactive nature of the software.
	In the 'Letters Shapes and Sounds' section, Child B was able to associate each of the five boxes below with a corresponding number in the following way Pink Box: Box Number 1 Green Box: Box Number 2 Yellow Box: Box Number 3 Red Box: Box Number 4 Blue Box: Box Number 5 This confirmed initial counting abilities assumptions included in the user model for a child of this age group.
	In the 'Create a Word' section, Child B noticed that the number of boxes appearing in the work area corresponded to the number of letters in the word he was instructed to spell. After repeated trials, he started to verbalize which box each letter of word is to be placed before actually dragging and dropping the letter onto the letter canvas.
	Child B noted that ء (*hamza*), was common to only two Arabic letters, أ (*Alif*) and ك (*Kaf*). He then asked to compose those letters to prove his acquisition of those letter shapes. He was successful in both tasks.
	Child B seemed to appreciate the child's voice providing feedback upon

	performance. Also, Child B noticed that the animation presented upon evaluating his response to letter and word creation was random. He expressed excitement about guessing which one of the animations will appear on the screen as soon as he hit the 'Done' Button.
	In the 'Find My Letter' interface, Child B chose to recognize the letters she composed, namely the letters ج (*geem*), ذ (*thal*), and ق (*khaf*) and was successful in all three tasks.
	In the 'Find the Missing Letter' interface, the student chose to insert a letter in the word ضفدع (*Defda'*). The letter to be inserted was randomly chosen by the application as the letter د (*dal*). The student immediately recognized the correct connection shape based on which letters were adjacent to the empty letter space on the work area.
Child C results	In the 'Find the Missing Letter' interface, the student completed 2 letter insertion tasks properly, for the word شطيرة (*shateera*), in which the letter ش (*Sheen*) was inserted and the word زرافة (*zarafah*) in which the letter ف (*fa'*) was inserted.
	Child C expressed she had already been introduced to the letters and associated words, and therefore wished to progress directly to the word composition tasks.
	Child C expressed this software is similar to others teaching French her parents had introduced at home. When prompted for reasons of similarity, she mentioned it also followed a strategy for introducing letters, in association with words and sounds.

	Child C verbalized that this software tool is a computerized version of his Arabic book at school. She noted her language books also used picture/letter association but that the audio association was only added by her parent or teacher at school.
	Child C mentioned that her teacher at school performed similar testing on students for letter composition. She noted his weakness in this area was placing shapes in the correct relative location. Seeing a work canvas revealing only possible, correct locations for atomic shapes composing a word helped her visualize relative locations for future compositions. Child C Mentioned that her aptitude towards using such an application is stronger on the week nights, when doing other homework's related work, as opposed to the weekend when she had the option of going out with this family and friends.
	In the 'Compose a Word' section , child C verbally counted the number of boxes available to her when composing a word and intuitively realized they corresponded to the number of letters in a word. She composed 2 words successfully in this manner.
	Child C realized she could only drag and drop letters onto the boxes appearing in his work area.
	Child C noted that she would like repeated expose to this application to internalize and absorb the information. She mentioned repeated exposure at different occasions would serve to reaffirm and strengthen her knowledge rather then feel the pressure of learning it all in one usage session.

	In the 'Compose a Word' section, she noted a finding reported by another student. Clicking on each letter in order to view all of its connection shapes suggests the shape that is to be placed at in relative to others letters in a word. This is evident for the position of the box the next letter is to appear in.
	In the 'Create A Letter' section, Child C chose to compose the letter و (*wow*). She composed it correctly and mentioned that this letter is composed of one atomic shape. She went on to compose another letter with two atomic shapes, غ (*gain*).
	In the 'Find My Letter' interface, the student was able to recognize 5 out of the 6 letter he was prompted to recognize. They were the letters, ه (*ha'*), غ (*gain*), ب (*ba'*), ي (*ya'*), and ش (*sheen*).
Child D results	Child D progressed through the 'Letters Shapes and Sounds' section verbally attempting to read the letters and words.
	Child D then progressed to the 'Find the Missing Letter' section. He chose this as the next logical task to complete after learning the letters.
	While completing the 'Find the Missing Letter' section, the student seemed to be enthused about the random location of the letter he is to find. He was heard trying to guess which box location will contain the missing letter. He completed two 'Find the Missing Letter' exercises for the words هاتف (*hattif*), he inserted the letter أ (*alif*), and for the word يد *(yad)* he insert the letter د (*Dal*).

	The student referred back to the 'Letters sounds and shapes' interface 3 times for 6 of the letters he was prompted to find. He was successful in all of his responses to the finding the given letter.
	He then progressed to the 'Create a Word' section. He heard the verbal request to compose the word أرنب (*Arnab*), Rabbit. He tried to phonetically sound out the word. The student looked troubled at composing the entire word. When reminded of the section asking him to only find one letter of the word أرنب (*Arnab*), he proceeded enthusiastically to that section, chose to find a missing letter in the word أرنب (*Arnab*), was able to extract the letter sound, drag and drop the letter shape and place the letter sound and corresponding shape ر (*ra'*) onto the correct location in the work area. When prompted to recognize the first letter of the word صمغ (*samgh*) glue, the student realized the first letter is to be ص (*sad*), and then picked out the correct letter connection shape from the menu of connection shapes for the letter sad. This drew on the student's phonetic association abilities of sound and letter shape as it pertains within a word.
	The student chose to refer back to the 'Find my letter' section as he enjoyed the random nature. He chose to locate the first letter of his name, ك (*kaf*). He was anxious to submit the correct response. As a result of successful completion of this task, he was encouraged to find al letters of his name, and successfully did so. They were the letters خ (*kha'*), أ (*alif*), ل (Lam), and د (*Dal*).

	The student was asked if he was amused and engaged as he was completing the assigned tasks. He mentioned he will ask his teacher at school to present similar evaluation techniques as presented by the application.
	The student made an observation when using the software that the 'Compose a Word' section has more letters to be filled in then does the find the missing letter section. This is because in the former, one is asked the complete the entire word while in the latter, he is asked to only fill in one letter.
	The interface asking the 'Find the Missing Letter' section the student chose the same word, أرنب (*arnab*) rabbit repeatedly in order to 'guess' which letter will be missing on his next attempt. Over several attempts, the student was asked to spell the entire word and he did so successfully. This exercise leads the student to learn the word one letter at a time.
	At this point, child D was confident to compose the entire word with in 'The Create a Word' section.
	In the 'Compose the Letter' interface, the student was able compose the letters ش (*Sheen*) and ع (*ain*) successfully.
Child E results	Child E realized all 5 words he was asked to compose were words he learned in the letters shapes and sounds section. He was successful in all of his composition attempts and translated each of the words to its English equivalent during his composition.
	One of the words, child E was asked to compose the word منطاد (*mintad*), air balloon. His strategy for spelling the word was to extract the phoneme starting

	the word. He realized it was the letter م (*meem*). He looked at the drop down menu for this letter's connection shapes. He chose the correct connection shape by making the analogy that م (*meem*), will, be 'holding the hand' of another letter from the left hand only since it is the beginning letter. He repeated phonetic extraction for all letters of the word.
	Child E was able to identify the correct positioning of each connection shape of the letter م (*meem*), based on their physical appearance and on the 'holding a hand' analogy he was able to extract from the connection letter shapes. He said the drop down menu of letter connection shapes allowed him for an easy comparison of all such shapes since they are listed on top of each other, helping him to come up with the with the correct connection shape for the letter.
	The child then browsed to the 'Compose a Letter' interface. He noted the difference from the 'Compose a Word' interface in that in this interface atomic shapes are being combined in order to create a letter, and each atomic shape appears the same no matter where it is to be placed, in contrast to letter connection shapes which differ based on their relative location within a word. When asked why he thinks this is the case, he explained that this is because letter shapes vary based on location within a word, where as the standalone letter, and its atomic shapes, will appear the same in all cases. He added atomic shapes must remain the same shape since they are being used in different letters which depend on them. He used a family-child analogy, designating the

	letters as the family, and the atomic shapes as members of that family. Child E mentioned that he/she preferred the favorable response to his interaction with the software then the negative scolding generated upon invalid task completion. He composed 2 letters with success, the letters ت (ta') and the letter ف (fa').
	In the 'Compose a Letter' section, the student suggested the work area onto which he/she could drag and drop atomic shapes to compose a letter looked like a robot's body composed of a head, feet, and an inner body. He composed the letter أ (*alif*) correctly.
	The student mentioned the body part name he was dragging and dropping the atomic shapes to.
	The student proceeded to the 'Find My Letter' section and chose to recognize the letters غ (*gain*) and ل (*lam*). He composed the letter ل (*lam*) correctly but could not recognize the letter غ (*gain*).
	The student then proceeded to the 'Find the Missing Letter' section. He chose to insert letters in the vocabulary words corresponding to the animals he viewed in the 'Letter Sounds and Shapes' section. They were the words, ارنب (*arnab*) and ضفدع (*defda'*). In the word ارنب (*arnab*), he inserted the letter ر (*ra'*), and in the word ضفدع (*defda'*) he inserted the letter د (*dal*).
Child F results	Child F initially started at the 'Letter Shapes and Sounds' section. He clicked on the letters until he found the first letter of his mother's name, ع (*ain*). He

	was then prompted to point out the shape of the letter ع (*ain*) when it is at the beginning of the word as is the case of his mother's name. He successfully did so and verbally repeated عصفور (*osfoor*), Bird, a word phonetically staring with the letter ع (*ain*), and showing it at the beginning position of a word.
	In the 'Find the Missing Letter' section, the student attempted to find the second missing letter in the word سيارة (*sayara*) car. The student cleverly realized that he could refer back to the 'Letter Sounds and Shapes' section, click on the button displaying the car, and see the word being spelled out at the bottom of the application. He then realized the missing letter was ي (*ya'*), at in the shape it would appear in the middle of the word.
	When clicking on the button displaying the word Balloon, the student verbalized that this word sounds the same in both Arabic and English.
	In the 'Find the Missing letter' section, the student placed the wrong connection shape for the letter م (*meem*). When the interface delivered negative feedback to the student upon his incorrect response, the student referred back to the 'Letter Sounds and Shapes' section to recognize the correct connection shape for the letter م (*meem*). He could extract it from the word it self by visually examining it and from the picture of the connection shape. He then proceeded to the 'Find the Missing Letter' section and inserted by dragging and dropping the correct middle connection into the word جمل (*jamal*), camel.
	Based on his learning experience through the 'Letters and Sounds' section, the

	student was asked to provide three words containing the letter ر (*ra'*), in the beginning, middle and end of the word. He provided the words ريشة (*reesha*), feather, for when the letter occurs at the beginning of the word, زرافة (*zarafah*), giraffe, for when the letter appears in the middle of the word, and عصفور (*osfoor*), bird, for when the letter appears at the end of the word. It should be noted that زرافة (*zarafah*), giraffe, was not the example for the letter ر (*ra'*), appearing in the middle of the word section for the letter ر (*ra'*). Instead, it was the word شطيرة (*shateera*), sandwich. This shows the student applying his knowledge of letter sounds and shape to other words acquired during the delivery of content pertaining to other letters.
	The student felt so confident of his knowledge of the word زرافة (*zarafah*), giraffe that he wished to spell it out in the 'Create a Word' section. He spelled the entire word correctly word by word.
	The student then chose the letter س (*seen*), and chose to complete all tasks associated with that letter available in the application. He was told what each interface provided. He was told to proceed to the next logical tasks after learning the letter shape and sound in the 'Letter Shapes and Sounds'. He quickly chose the 'Find my Letter' interface, because he felt confident that he would recognize the shape based on acquired knowledge. He then proceeded to compose the word starting with the letter seen. He realized it was the word سيارة (*sayara*), car, and progressed through the list box to hear that prompt. He

	composed it letter by letter by means of phonetically spelling out the word and dragging on dropping each corresponding letter to its location in the work area. He also completed the 'Create A Letter', and 'Find the missing Letter' tasks for the letter س (*seen*).
	The student seemed to be more enthused when a child's voice then the examiner's congratulations upon successful completion of evaluation tasks. This was concluded when the student laughed, smiled and repeated the positive remarks made by the child's voice.
Child G	The student firstly browsed the initial interface delivering letters shapes and sizes. He scrolled through the entire 28 letters and clicked randomly to understand the functioning of the interface. He realized each click on a letter displays its standalone shape, along with words and letters shapes corresponding to each of its letter connection shapes.
	The student proceeded to the 'Find My Letter' interface. He scrolled through all prompts to find a given letter and realized the function of the interface before actually attempting to complete the task. He was able to recognize 3 out of the three letters he chose to find. They were the letters م (*meem*), ي (*ya'*), and أ (*alif*).
	The student browsed though the remaining interfaces to realize the function of each. He preferred to complete two tasks from the 'Compose a Letter' Interface corresponding to two of the letters he was prompted to find in the 'Find My Letter' interface. They were the letters ي (*ya'*), and أ (*alif*). He was

	successful in both of those composition attempts.
	In the 'Find the Missing Letter' Interface, the student selected to find a missing letter in the word منطاد (*mintad*). The missing letter as displayed by the interface was the middle letter ن (*noon*). He was unsure on which connection shape to insert into the location, and referred to the 'Letters Shapes and Sounds' interface to remind himself of the connection shapes for ن (*noon*). After a quick glance, he was able to insert the correct connection shape and receive the instantaneous feedback.
	The student then proceeded to the 'Compose a Word' section. He chose to compose the same word as he worked on in the 'Insert the Missing Letter' section, the word منطاد (*mintad*). He completed the task successfully and mentioned the spelling of the word was still fresh in his mind. He felt confident in his understand of word composition and phonological disassembly of given words that he went on to successfully compose the word نخلة (*Nakhlah*)

Table 6 Testing and evaluation results on children A through G

User Evaluation Results Interpretation

The following table 7 summarizes the empirical data mined from the complete user testing process compiled in Table 6.

Child	Find My letter		Compose a Letter		Find Missing Letter		Create a Word		Total Attemp
	Successful Task	Unsuccessful Task	Success Task	Unsuccessful Task	Succes Task	Unsuccessfu Task	Success Task	Unsuccessf Task	
Child A	5	0	4		2	0	2		13
Child B	3	0	2	0	1	0	4	1	11
Child C	3	0	2	0	2	0	2	0	9
Child D	5	0	2	0	3	0	1	1	12
Child E	1	1	3	0	2	0	5	0	12
Child F	1	0	1	0	2	1	2	0	7
Child G	3	0	2	0	1	0	2	0	8
Total	21	1	16	0	.13	1	18	2	73

Table 7 User testing results summary

Based on the above empirical data of user testing, the results demonstrate overall success in the performance of the students in using the software developed to deliver introductory Arabic language. Further, observations made during the testing process and recording of student interaction is another indication of the success of the content delivery application. More concluding remarks will follow in the final chapter.

4.2.2 Schedule Plan

The following schedule plan outlined in Table 8 was created to measure the speed of accomplishing the tasks previously defined.

Task	Estimated Completion Time	Actual Completion Time	Reason for variation
Task 1, step a	3 hours	5 hours	- changed interface after it was reviewed by student
Task 1, step b	6 hours	6 hours	
Task 1, step c	2 hours	2 hours	
Task 1, step d	8 hours	10 hours	- Coding errors needed to be fixed.
Task 2, step a	2 hours	2 hours	Interface was designed previously on a paper prototype, and implemented in the development environment.
Task 2, step b	½ hours	½ hour	This is a simple interface.
Task 2, step c	1 hour	1 hour	
Task 2, step d	1 hour	1 hour	
Task 2, step e	1 hour	1 hour	
Task 3, step a	1 hours	1 hours	

Task 3, step b	1 hour	1 hour	
Task 3, stab c	1 hour	1 hour	
Task 3, step d	10 hours	11 hours	- Coding errors needed to be fixed, and the verifications need to be conducted per letter and per word.
Task 3, step e	1 hours	1 hours	(this stage simply set the way for being able to import a set of audio recordings into the run time environment of the application)
Task 3, step f	1 hour	1 hour	
Task 3, step g	1 hour	1 hour	This routine will be repeated in more sections to come.

Task 4, step a	1/2 hours	1/2 hours	This is the same list of words from the previous task.
Task 4, step b	½ hour	½ hour	Can import the same recordings from task 3, step c
Task 4, step c	5 hours	8 hours	(- implementing dragging and dropping functionality took longer then expected)
Task 4, step d	1 hours	1 hours	The same interface is imported from task 3, step a
Task 4, step e	5 hours	5 hours	This is accomplished per letter, per word.
Task 4, step f	1 hour	1 hour	This is accomplished for all letters, in all words
Task 4, step g	1/2 hour	½ hour	Import same recordings from task

			3, step f
Task 5, step a	1/2 hours	1/2 Hours	(-this is the same list of words to be imported from task 4)
Task 5, step b	1/2 hour	1/2 hour	This is the same list of recordings from the previous section.
Task 5, step c	3 hour	3 hours	The same routine is imported from task four however, the picture box labels involved in the drag and drop operations for this interface must be put in place
Task 5, step d	3 hour	3 hour	This is accomplished per letter, per word.
Task 5, step e	1 hour	1 hour	
Task 5, step f	1 hour	1 hour	
Task 6	This is an on going efforts tested on a		

	set of students for a period of 10-15 minutes daily for over 4 weeks.		

Table 8 Schedule plan describing performance rate for task completion

Table 8 shows the estimated and actual speed for task design and completion. Due to design time discovery of interface errors, omissions and run time student reviews, the table reveals were some discrepancies between estimated and actual speed of certain task design and completing. In essence, these discrepancies were a result of either adding new functionality to the existing interface or resolving coding or interface errors.

On the other hand, certain tasks were completed in the estimated time. These tasks were previously designed on a paper prototype its design was studied in detail prior to design. This helped to reduce defect and error resolution overhead and so design was completed in the estimated time.

4.2.3 Resource Specification:

The following list defines the required software development resources:

a) Arabic instructional material for grade one for the creation of appropriate graphical representation of Letter Sounds and Shapes.

b) Digital Scanner to transform hard copy of graphical representation to digital format.

c) Voice recording of letter sounds associated with each letter.

d) Microphone to record all letters and associated words.

e) Parental recordings to be supplied by each student's parents and imported at run time upon verification of student input.

f) Graphical images expressing happiness or disappointment to be presented upon verification of student input. Such images will be chosen appropriately for the age under consideration.

g) Designate seven children to test out the software and provide feedback about its functionalities and collect task success data.

h) Arabic enabled keyboard to write out Arabic letters.

i) Mouse for student input.

j) Speakers for audio output.

k) Installation of the development environment, in this case, Visual Basic Express 2008.

4.2.4 Program Size

As per PSP specifications, the estimated program size for this project is based on the lines of code generated to meet the tasks and objectives previously defined. This is measured using an internal counter in the programming environment, Visual Studio in our case. The total TOC of this program is about 19691 lines of code. This value may vary depending on whether or not new tasks will be added in the future to the existing ones. This software was written using Visual Basic Express 2008, compiled on Windows XP, and run on a computer with 1G RAM.

4.2.5 Defect Report

A defect is suspected every time a change is made in the code. Defects arising in this way were kept track of and recorded during the implementation of the software project. In order to reduce the occurrence of such defects, code reviews were conducted for every implemented segment before running the software.

The PSP process prescribes the creation of a tailored check list developed as a remedy for the compile and test defects found in earlier version of the software. In other words, it is evident that PSP reveals defects which have a bearing on 'establishes design completeness criteria' in the resulting software. This list of defects is used to assess the quality of the development process as prescribed by the study reported in [Silberberg, 1998]. In this way, the PSP helped identify generic defects to be avoided in all of the interfaces of the software.

The following is a list of all defects detected after designing and running the software.

Letters Shapes and Sounds Defects

a) Graphical images for letters 3 through 5 were too big to be display at the designated picture box.

b) Letter 12 was showing the wrong graphical files once clicked on.

c) Letter 6 was not correlated with the correct audio file pronouncing it.

d) Scrolling to the right showed the left most letters repeatedly over buttons.

e) The interface did not initially show all possible connection shapes of a letter at the same time. Rather it showed tab pages and a student needed to traverse those pages to access a letter's different shapes. The interface needed to be changed in order to show all connection shapes at the same time for reasons of comparison and easy access.

f) The wrong graphic was displayed for the 6th and 8^{th} letters.

g) The graphical representation for the 25th letter was too large to be displayed in the designated display box.

Find my Letter Section Defects

a) Graphical images for letters 3 through 5 were too big to be viewable from the designated picture box to contain

b) In the 'Recognize the Letter' interface, the subroutine generating random locations repeatedly placed the letters in the same location.

c) When prompted for recognition of the letter ب (*Ba'*), the letter ث (*Tha'*), was shown two times to the student from the list of letters to choose from. It is only to be displayed once as the student should have a selection of 4 letters when attempting to recognize any given letter.

Insert a Letter Section Defects

a) Insert of letters was not being executed properly for the letter ج (*jeem*),and consequently, the word جمل (*jamal*), camel, was not being spelled properly

b) For the word أرنب (*Aranb*), Rabbit, the letter ر (ra'), was being inserted in two locations next to each other instead of one location.

c) For the word سيارة (*sayara*), car, the letter س (*seen*), was being inserted in the wrong location.

d) For the word يد (*yad*), hand, the letter د (*dal*), *was* not being inserted into its correct location.

Compose a Letter Section Defects

a) There was no 'Clear' button which erases shapes from the work area.

b) There is one picture box inside of another. When a shape was placed inside of the bigger box, the inner box also received the same shape into it due to lack of checking on the range of the inner box. This was a defect since a shape should only be placed in one box upon a drag and drop operation. Mouse coordinates must be checked to see which box the shape is intended to go.

c) If the student did not choose any letter to compose and went directly to dragging and dropping shapes onto the boxes in the work area, he/she was not notified that he/she must first choose a letter to compose and that his actions cannot be processed nor verified.

d) The wrong calculations were being made when deciding on where to drop a letter after dragging. This resulted in letters being dropped in the wrong locations or not being dropped at all upon release of the left mouse button.

e) Atomic shape 6 was not being dropped onto any box in the work area after a dragging operation.

Create a Word Section Defects

a) There was no 'Done' button was added to the interface for the student to be able to indicate completing the word.

b) No button was added initially which instructs the student how many letters the word to create is, or which word to create. The initial interface verified only the letters being placed in a box without considering when the last letter is to be expected.

c) There was no 'Clear' button which erases letters from the work area.

d) Once a student clicks on a letter, all of its shapes drop down below it in a selectable menu for the student to choose a letter shape to drag and drop. When a student clicked on another letter, the menu of shapes for the previously clicked letter did not disappear. It is more logical for only one letter's menu of connection shapes to appear at any given time.

e) The ending letter shape for letter 19 was not being dropped onto any of the designated boxes of the on release of the work area.

f) No checking was in place for situations where a letter is not supposed to be attached to the letter before it. Verification mechanisms were needed in order to ensure all aspects of the 2 dimensional grammar defining letter connection styles were implanted by the application.

g) Performance of the child did not initially receive any audio or visual feedback based on correctness. Positive Feedback was added for correct performance, and negative feedback was embedded for incorrect performance.

h) For composing the word Box, placement of the last letter ق (*khaf*), was not verified correctly. The interface first indicated it was the correct letter to place, and consequently, indicated it was the wrong letter.

i) The 'Done' button did not initially verify the spelling of the word under consideration. Verification of every letter composing the word was added to verify correct spelling.

j) The menu for the letter ت (*Ta*), ط (*Tat*), ظ (*That*) did not initially contain all of its possible connection shapes. They were added as they were required in the spelling of the words.

k) Upon correct spelling of the word, no visual representation of the word was displayed upon successful completion. This word representation was consequently added so the student could see the actual word he/she or she was trying to spell.

l) For the letters ج (*jeem*), س (*seen*), ش (*sheen*), and خ (*kha'*), the menu of all of the letter's connection shapes did not display long enough for the student to choose a shape to drag and drop.

m) No audio command was in place asking the student to compose a given word. This must be added in case some students are unable to read the English commands in the selection box.

n) The right number of boxes corresponding to the number of letters in a word was not displayed. It was always the same number of boxes. This was changed to show the student only the number of boxes needed to compose the word under consideration.

o) For the letter ه (*ha*), its menu of connection letters showed all the time. It was changed to be revealed only when it was clicked on.

p) After a connection shape was chosen for a letter and placed in the work area, the menu of the letter under consideration did not disappear. Letter connection shape menus needed to disappear once a student chose a given connection shape. The interface was changed to make this menu disappear when a letter was placed in the work area.

q) Initially, the number of letters pertaining to each word was kept track of, for verification purposes. This strategy was then discarded as the checking process is now taking place on a per letter basis, so letter count is irrelevant.

General Defects with the Application

a) The application included a section where children were able to draw any given letter using the mouse on a pad, simulating a paper and pencil exercise. However, as the student's output cannot be validated for correctness of such an exercise, it was excluded from the application.

b) The 'Find my Letter' interface was missing from the tool; it was overlooked as a prelude to the 'Compose a letter' interface.

c) The 'Insert the Missing Letter' interface was missing from the tool; it was overlooked as a prelude to the 'Compose a word' interface.

4.2.6 Compile Time

The compile time for this project was minimal, due to facilities and features offered by the programming environment. These features helped reduce syntactical errors due to immediate fixing of compiler errors. Compile time errors were also reduced due to code reviews conducted on the code in order to minimize errors and logic flaws. The total time to compile and fix coding problems time is about 3 hours.

4.3 Review Techniques and Design Completeness Criteria

This phase of the PSP process adds review techniques to help resolve defects in the software under consideration. The main method of accomplishing this is to add code and design reviews to the development process. The list of defects realized as a result of producing a test report is analyzed. Consequently, this data is used to create a tailored review checklist to be used as quality assessment measures. This checklist focuses on design completeness criteria, design verification, and consistency techniques. Based on the defects discovered as a result of the testing process, the following review checklist will be used to achieve a minimum level of design quality and consistency.

a) All graphical representations used by the software must be assigned the same size specifications. This is a manual process of opening each such file and changing the size to a standard one, which are the dimensions 548 by 202 pixels.

b) Based on omissions made on the interface of the compose a letter functionality, reassessment of the interface design must take place to ensure all needed input or output buttons are available to the user. A code review must also follow this assessment.

c) Based on omissions made on the interface of the compose a word functionality, reassessment of the interface design must take place to ensure all needed input or output buttons are available to the user. A code review must also follow this assessment.

d) Thorough code review and testing must be made on the code snippets placing a letter inside of a designated box in the display area. This is to ensure letters are being placed in the correct location upon dragging and dropping.

e) Thorough code reviews and testing must be done in order to ensure the correct audio files are being played in the correct parts of the code.

f) Perform a code review intended to remove all parts of the code not to be included in the final version of the software developed.

g) Perform an analysis of the word composition section which intended to ensure that the entirety of the two dimensional grammar is being applied to the letter connection model.

h) Perform a code review on all available interfaces in the software to ensure that users are able to interact with it in a sound, reasonable manner to resolve issues such as letter menu appearing at any given time in the compose a word section, or to ensure all relevant information is available at the same time to the user. This code review is also intended to ensure user receives enough instruction from the software to be able to successfully complete the tasks.

i) Perform a code and interface review to ensure all pedagogically logical interfaces are present in the application and appear in an intuitive order among other interfaces.

Another objective of the PSP2 phase is to create a list entailing several design completeness criteria. This list is based on the defects reported in the defect report. This is intended to ensure that all initial language teaching objectives are met through the design to be delivered by this work and that all major defects are resolved. The following is the design completeness list

Design Completeness Criteria

The following design criteria checklist was arrived at upon examination of the defect report. Each criterion ensures that none of the defects previously detected will be repeated upon future code revisions.

a) All the 28 Arabic letters are delivered with the following

1) 3 graphical representations of the letter in the beginning, middle and end of the word

2) Words depicting the letter in all of its possible connection shapes.

3) Words containing the letter at various connection points.

4) Audio files corresponding to words associated with the letters.

b) An interface delivering this content in a way easy for a child to understand, use and access.

c) All interfaces appear in a pedagogically feasible manner.

d) A verifiable method of enabling children to compose any given letter.

e) An interface delivering this testing mechanism in a way easy for a child to understand, use and access.

f) A verifiable method of enabling children to compose any predefined word upon prompting.

g) An interface delivering this testing mechanism in a way easy for a child to understand, use and access.

h) A verification system suitable for a child of grade one level, incorporating parental stimulus for both positive and negative.

i) All content relevant to this age group is delivered in one of the interfaces of the application.

At the implementation level, progressing through our thesis efforts, it became evident that there were two design aspects dynamically interacting in order to produce the resulting software implementing the content system of our work. Firstly, the language delivery system put forth the content to be delivered, mechanism of delivery and included the user model in order to deliver a personalized delivery process. This content and user models of our delivery system provided the initial design and implementation criteria for the software. Faithful adherence to the PSP process as described in the study related in [Silberberg, 1998], revealed run time defects in quality and functionality, exposing design time misjudgments.

For example, it become evident that some quality requirements criteria for the software were lacking from the initial language delivery system and that most focus was on the content and delivery process, without identification of delivery details. Other functionality type requirements were found to have been specified. However, run time testing, as prescribed by the PSP model, lead to the isolation and consequent resolution of implementation defects. Evidently, adherence to the PSP development process produced a software application applying the original content delivery system in an effective, quality-assured, and presentable manner.

In this way, the dynamic interfacing of the language content delivery system and the PSP process yielded a software tool drawing on principles from both design perspectives. Differing aspects of the software are attributable to both the PSP model and the user and content models of our delivery system.

Chapter 5 Conclusions and Future Work.

In this chapter we provide a summary and report our observations and conclusions arising from the content delivery system and the subsequent software development and evaluation process in this work.

5.1 Summary

We have devised and demonstrated the application of a content delivery system to provide foreign-language instruction for grade one level students learning their parent's mother tongue. The content delivery mechanism extracted relevant content suitable for the target age group, and put forth a content delivery tool designed to be engaging and instructional in nature by incorporating generic user model descriptive of children within this age group. These characteristics were collected by observing seven children as they were acquiring linguistic content in a classroom environment. Students in this group demonstrated common characteristics such as having a short attention span, the tendency to express visible pleasure upon receiving direct positive feedback, showing apprehension upon negative feedback and a willingness to acquire linguistic content in a new, stimulating manner. The skills assumed on the children's side were the ability to count to ten, recognize colors, and associated numbers with visible objects in a counting exercise.

These characteristics and preferences were then translated into a user model to be incorporated into the delivery process of the language of choice in order to produce a stimulating, learning experience for students. As an application of the language delivery system, the Arabic language was selected to be the language of choice to be delivered. This was accomplished by modeling a fragment of Arabic linguistic content, and thereby putting forth a model of linguistic delivery to be followed for the instruction of introductory content of a language.

During modeling and corresponding tool development process, relevant research areas were reviewed and ideas from them were incorporated into the delivery process. Firstly, principles of CALL as outlined in the study reported in [Warschauer, 1996] were used as a guideline to implement the computer application manifesting the delivery system, more specifically, a language teaching tool for the Arabic language. Secondly, pattern modeling, recognition, and extraction principles were central in the process of presenting and evaluating a students' ability to recognize and compose letter sounds and shapes. This research also drew on phonetic principles exposed in the related study discussed in [Jong, 2007], introducing letter-sound and letter-word associations to deliver to the student letter recognition and reading skills as well as a phonetically related set of vocabulary words. This list of vocabulary words were extracted from instructional material introducing the Arabic letters; 28 words corresponding to the 28 Arabic letters.

Initially our prototype implementing the language content delivery system started with an ad hoc software development procedure. It was then decided to follow a structured software development process, namely the PSP process as a single person effort to produce a prototype implementing the proposed system. Faithful adherence to the development methodology of this development process, more specifically, the PSP0 phase, in which tasks required to implement the content delivery and evaluation tasks children of this age group need to acquire the content previously decided upon, helped identify omissions in the kind and amount of content and evaluation sessions. A structured, chorological study of the curriculum under consideration revealed the need for insertion of two additional interfaces to the software being developed so as to produce a logically ordered and pedagogically structured learning experience for children interacting with this software. The first interface to be inserted was the 'Find my letter', in which a student is prompted to find a given letter among four others. From a pedagogical perspective, this interface is a sound evaluation scheme to be provided to the child after he/she has been introduced to the 'Letter Shapes and Sounds' interface. The study outlined in [Horner, 2001] confirms the advantage of viewing 'printed' alphabet letters to their recognition. As per these findings, the insertion of this interface succeeding the letter introduction is justified. As discussed in the study relayed by [Horner, 2001], after a child has been exposed to a set of letters in viewable print, the set of skills he/she has acquired lends itself for evaluation for letter recognition. Letter recognition is most suitably measured by testing a student's ability to isolate a letter amongst a number of others upon verbal instruction. Letter recognition also forms a basis for consecutive content acquisition or evaluation tasks.

The other interface added as a result of PSP0 implementation, was an interface in which a child is prompted to find one, randomly chosen, missing letter within a word. This test process is a logical prelude to the evaluation task prompting the student to compose the entire word. This is because before a student is able to compose an entire word, he/she must have been able to compose a word letter by letter. 'Find the Missing Letter' interface was inserted for this reason.

The addition to these interfaces as per PSP process observance reveals the true adaptive capacity of our language delivery system and corresponding software prototype. This adaptation is an example of how new material can be incorporated into the delivery process on the vertical scale of expandability described previously, allowing for same language extensions. It also reveals the systemic, PSP bounded development process our software development efforts followed to produce the final prototype.

The resulting software tool incorporated and implemented the proposed system applied its language delivery to the Arabic language. The tool was initially tested on a set of three students. In order to affirm the results recorded from these children, an additional set of four children were asked to take part in the testing process. Their interaction, visible cues, task completion and success while using the software prototype were recorded and one student's usage session was video recorded.

5.2 Observations

The aptitude and success of the students when using the software suggest the language delivery process devised in this work performs effectively to introduce children of Arabic immigrant background to their parent's mother tongue, as demonstrated by the following observations.

All seven children were noted to have a good overall experience with the software. They exhibited physical cues to this effect, such as repeating audio segments generated by the application, reading content from the 'Letter Sounds and Shapes' section out loud, associating the Arabic words and letters with their English equivalents, and relating interaction with this software to other learning situations they have previously experienced. The readily viewable atomic shapes were used almost flawlessly by the students when prompted to create letters. Overall, the atomic shapes were recognizable and applied with ease to the creation of each letter. When creating a word, students were able to spell out words and drag and drop the correct letters in phonetic order within the word. Being presented with a menu of all possible letter connection shapes, it was observed that students were able to recognize the place to put each connection shape, considering its relative position within a word. This is because for some letters, a visual examination of any of its connection shapes helps to reveal the correct location. Spelling out words was facilitated by the fact that students could refer back to the initial interface introducing letters and their corresponding shapes. When the spelling of an entire word was too difficult for a student, he/she could refer back to the 'Find the Missing letter' interface and look at which letters are filled in and which one is missing. Repeated use of this interface gave the student the ability to spell out an entire word.

All seven students were able to identify a letter among four others in the 'Find the missing letter task', based on learning acquired from the previous lessons on letter shapes and sounds.

Suggestive evaluation aid tools such as presenting a work canvas specifying correct letter locations seemed to facilitate the evaluation sessions for each of the students. This helped the students complete the evaluation sections within a framework of 'correct locations' to drop shaped and letters upon, and therefore, for a positive, successful evaluation experience. Further, English transliteration of the Arabic words to be spelled aided the students to phonetically discern the Arabic letters to be inserted while spelling out words. The testing process conducted as part of the PSP process development cycle served to expose the quality of linguistic acquisition of the student. Two factors identifying quality of acquisition were exposed, namely, the student's achievement in successfully completing the evaluation sessions embedded in the application, as well as his/her positive aptitudes towards repeated exposure to the tool. This manner of testing relays the interaction of the student with the application and records their visible reactions, such as browsing, mouse clicks, dragging and dropping of object in response to evaluation routines and audio and visual stimulus.

This testing scheme is appropriate for the age group under consideration as is stipulated by the authors of [Zurawsky, 2006]. A full usability test is not feasible for this age group, due to their age and low attention span. Guided testing also empowers students with a roadmap of success using the application. This provision is provided for the young age of the students and their limited memory and attention span.

5.3 Conclusions

Table 7 summarizes the test results of the 7 children who interacted with the software. The task completion and performance data recorded for each of the tasks categories reveals a good success rate when relating the total number of successful tasks to the total number of attempted ones. The following success percentages are calculated per task category. 95.4% successful task completion for the 'Find My Letter' tasks, 100% for the 'Compose a Letter' tasks, 92.8% for the 'Find the Missing Letter' tasks, and 90% for the 'Compose a Word' tasks.

Further, the task completion and performance data calculated for the collective performance of the students reveals a good success rate when relating the total number of successful tasks to the total number of attempted ones, across all categories. Viewing all the children as a group, there were a total of 73 tasks attempted by the seven students and 69 of the tasks were completed successfully while there were only 4 tasks completed unsuccessfully. This ratio results in an overall 94.5 % success rate in the completion of the tasks attempted.

This table also reveals that no student completed more then two tasks unsuccessfully out of the total number of tasks he/she attempted. The success percentage for completing 'Find my Letter' tasks confirms the students' letter recognition abilities. The success percentage for the 'Compose a Letter' interface reveals an understanding of atomic shapes concepts and letter recognition. The success percentages for the 'Find the Missing Letter' and 'Create a Word' interfaces reveal excellent phonetic extraction, connection shape recognition, and vocabulary acquisition. Overall, the results confirm that each of the students interacting with the software demonstrated an internalization of the language content delivered, applied his/her acquired knowledge to complete tasks and benefited from the suggestive nature of the evaluation sessions.

The children were observed during their interaction with the software and their verbal and physical responses to the software were recorded. It was evident that children applied relevant linguistic, shape recognition, and composition skills into their task completion process. Child A drew on knowledge acquired during her interaction with the software to complete current tasks. She visibly displayed letter-word and atomic shape-letter association. She noticeably benefited from the graphics available on the interface as evidenced by her verbalization of newly acquired vocabulary. This behavior was anticipated by the user model and resulting application design.

Child B verbally sounded out the English equivalents of all the words he was presented with on the 'Letter Shapes and Sounds' interface. This reflects vocabulary internalization. He also acquired spelling abilities as evidenced by his success in the word composition and letter insertion tasks. When prompted, the child displayed an understanding of the atomic shapes concept through his ability to identify common shapes contained in several letters. He also displayed color-number association, counting abilities, extracted phonemes from given words, and was able to use and manipulate the hardware with ease, as presumed by the user model. He was also noted to be attentive to the suggestive nature of the application. The child referred to relevant interfaces within the application when required. The child used adjacency of letters as a concept to decide on correct connection shapes.

Child C was the first to pass over sections delivering content with which she was already familiar. Such behavior was accommodated by the application and anticipated by its design. She also picked up on the suggestive nature of the application when spelling out words, realizing that the number of boxes appearing in her word area is the same number of letters composing the word under consideration. She performed phonetic disassembly of a given word to spell it out. This ability was presumed by our content delivery system. The interface presenting letters and their connection shapes evidently helped this child choose the correct connection. Because of their close physical proximity on the interface, children were able to choose connection shapes based on appearance in relation to others, and related each shape to a position within a word. The child displayed an understanding of atomic shapes and their capacity to compose letters by counting the number of atomic shapes required to compose any given letter.

Child D confirmed the effectiveness of pedagogical sequencing adopted by the application by progressing through the multiple application interfaces in the order they appear. Having progressed in this way, he was also keen to refer to earlier interfaces for reminders of the content when required. He displayed phonetic association between letters and words termed 'Phonetic Similarity' by an earlier study outlined in [Jong, 2007] This child used the capacities of the application to find the letters of his own name, which confirms the presumption of our work about the benefits of using relevant, familiar words to the student. This was also confirmed in the study reported in [Jong, 2007]. He appeared visibly engaged in the application and interacted with it in anticipation of the random feedback he came to expect. Child E displayed an understanding of the delivered vocabulary by recognizing where he was initially introduced to it, its meaning and composition. He displayed phonetic extraction ability. He also demonstrated an understanding of connection shapes based on each connection shape's visible appearance. He compared atomic shapes to letter connection shapes and correctly identifying that while the former always appears the same, the latter differs based on its position within a word. Child F exhibited phonetic association of a single letter with multiple words. He was also able to provide vocabulary containing a letter at various parts of the word. He also referred to prior sections to successfully complete current tasks. He displayed overall enjoyment as he progressed through the application, especially when a child's voice congratulated him upon successful performance. This reaction was anticipated by our application and, hence, the inclusion of a child's voice in the feedback provided by the application. Child G progressed through the interfaces in a pedagogically ordered manner, completing the more basic tasks first and then progressing towards the most complex tasks. He referred to earlier sections of content to complete certain tasks, and exhibited increased confidence as he performed more tasks with success.

Child B went on to recommend the software for future usage and seemed visibly engaged in the feedback mechanism. He related the current content to previously offered linguistic instruction. Child C verbalized her appreciation of the delivery tool by indicating that she feels comfortable using a visible working canvas onto which he can drop atomic shapes. The teaching methodologies adopted in our study were associated by this child to other linguistic instruction previously received. This was another presumption of our content delivery system. Child E made analogies relevant to a child of his age concerning his work area in the composition tasks. He compared the work canvas to a robot's body and named the body part he was dragging and dropping atomic shapes onto.

The following list summarizes the observational findings of our qualitative evaluation:

1) Students drew on relevant knowledge to complete current tasks.

2) Students verbally demonstrated letter-sound associations.

3) Students displayed vocabulary internalization by associating vocabulary, graphics and audio.

4) Students acquired the ability to compose letters and words as per the proposed system.

5) Overall, the characteristics and behavior of the students were accurately described by the user model.

6) Students benefited from the suggestive nature of the application:

    a) Students counted the number of boxes spelling out words.

    b) Students determined possible locations for atomic shapes by inspecting the work canvas.

c) Students relied on connection shape menus and adjacent letters to select connection shapes composing a word.

7) Students displayed phonetic extraction abilities.

8) Students benefitted from the pedagogical sequencing incorporated by the application.

9) Students showed the application bears relevance to the language skills of this age group by using it to compose and learn relevant words.

10) Students were visibly engaged in the audio and visual feedback of the application.

11) Students were able to distinguish different aspect of the content delivery system and indicate the context of where each one applies.

12) Students benefitted from the flexible browsing provided by the application and referred back to relevant content when necessary.

13) Students showed that the feedback process increases the confidence level of the children as they progress and successfully complete tasks.

14) Students referred the software for future usage and advanced content.

15) Students drew analogies between our delivery process and concepts favored by students of this age group such as referred to a robot's body in reference to the work canvas for creating a letter, 'friends holding hands' in reference to the physical appearance of some connection shapes, and using the word composition features to compose personal words such as names.

Based on our findings during the evaluation process, we conclude that the language delivery system and corresponding tool effectively serve the intended purpose of delivering elementary linguistic content to children of grade one level. The overall success of the students in completing the tasks and favorable aptitude towards using the software indicate that this software is effective and useful in conveying the content under consideration, for the target age group.

Considering the performance of the student as they progressed through the application and the built in expansion schemes of the content delivery system, we noted the proposed system is promising in its ability to qualify the student to acquire higher levels of learning for the language it is applied to.

Based on these findings, the PSP software process used in the software development model applies well to software projects in which clear objectives are defined in terms of functionality. The findings also show that PSP enhances the quality of software when it is followed during implementation and testing.

Faithful adherence to the PSP development process provided the following benefits:

a) A structured development process leading to a thorough content delivery application.

b) A task identification process encompassing the tool content delivery objectives.

c) A defect identification mechanism and resolution methodology arising by means of defect reporting giving rise to design review checklist and defect report criteria to be consulted for future code revisions

d) A user testing methodology revealing user interaction and aptitudes towards using the application.

e) A way to calculate development scheduling, resources, and corresponding program size

Further, the choice of the PSP development process, as opposed to using other models such as the water fall model, is deemed justified. The PSP process allowed for identification and resolution of defects and errors elicited at every stage of the development process, generating an assessment strategy for the quality of the software application.

As far as limitations of the content delivery system of our work, it was realized that despite the engaging and stimulating nature of the delivery process a student experiences, children did not use the application for a period equaling classroom instruction time. Most students used the application for a period between 10 to 50 minutes as opposed to 50-60 minutes allotted for classroom instruction. For four of the seven children who used the software, it took about 5 minutes of using the software before actual learning and visible acquisition and successful evaluation sessions were noted. This time was used to explore the application and discover its functionalities.

5.4 Future work

This research can be expanded in several directions, described as follows. Most notably, the linguistic content delivery system devised in this work could be adopted and extended to the delivery of languages other than Arabic. Modeling the alphabets of other languages could be approached following the same ideas proposed for Arabic language letters. This is because atomic shape extraction from letters is a process applicable to letter modeling of any given alphabet. Connection shape extraction is a process most suitably applicable to the modeling of cursive languages such as Urdu or Persian due to the differing shapes letters take on when they appear written cursively. Further, the principles behind word composition tasks and phonetic extraction exercises offered to the student are applicable in the creation of any word, in any language. In order to spell out a word, a student should extract letter sounds and realize their relative position within a word. This process provides a basis to introduce vocabulary spelling and meaning, regardless of the language under consideration. It also serves as an effective spelling and phonetic sound extraction exercise. Shape recognition is also included in spelling activities, and this remains applicable to languages where letters remain the same shape regardless of relative position within a word. In this sense, this language delivery principles adopted by our system are applicable to most, if not all language instruction.

In essence, further adaptations of the delivery system are applicable to a variety of linguistic instruction. Conceivably, this could create a basis for an expandable encyclopedia of language teaching.

Another possible future work is to accept student inputs using pen devices. This endeavor may eliminate the need to present the student with atomic shapes when prompted to compose letters. Character recognition technologies would be the ultimate method of verifying student input.

Another dimension of expansion is to support and incorporate speech recognition technologies within the proposed work, whereby student vocabulary pronunciation is verified against expert knowledge. This can help advance a student's phonetic and linguistic progress. This is also expected to advance progress in speech recognition within the realm of CALL based linguistic instruction.

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