MacVenture: An iPad Application Design for Social Constructivist E-Learning

MACVENTURE: AN IPAD APPLICATION DESIGN FOR SOCIAL CONSTRUCTIVIST E-LEARNING

BY

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For my family, especially Bruce.

Abstract

Several countries are beginning to introduce computer science education at an elementary school level in response to the increasing demand of technologically skilled workers. In the transitionary period of establishing the curriculum and expectations, there is an opportunity to revolutionize certain aspects of the teaching and learning process within the classroom. In many ways, we can use technology to enhance this experience. For teachers, it can automate repetitive tasks, as well as provide immediate feedback on class progress. For students, it can offer engaging interfaces, helpful hints and innovative ways to collaborate with one another.

To put this challenge and opportunity into context, we review what is known about learning theories, and survey existing applications. A large majority of these applications support *behaviourist* learning styles, what most would call "traditional" teaching methods. Much like pen and paper drill exercises, they reinforce information previously presented to the user for passive consumption. This is in spite of the fact that academic researchers strongly favour *constructivist* and especially *social constructivist* methods. In fact, this perpetuates a known gap between theory and practice in education, and may be contributing to the lack of adoption within the classroom.

MacVenture is an iOS application designed to facilitate social constructivist teaching styles by allowing students to create gamebooks for themselves and for their peers by incorporating material from across the curriculum. This work outlines the structure and design of MacVenture, presents examples to illustrate the range of uses it supports, and discusses proposed future developments to enable new methods for collaboration among peers, and new motivational and analytical tools for teachers.

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Chapter 1

Introduction

In this chapter, we discuss the introduction of software applications into pedagogy, providing the motivation for the development of effective software designs in educational technology. In Section 1.1, we give an introduction to the field of educational technology (including our working definition of educational technology, e-learning, and m-learning) and provide an overview of learning theories. Additionally, we delve into constructivist learning with tablet-based applications, and discuss some of the hopes for and shortcomings of this field thus far. In Section 1.2, we give our motivation for creating and presenting the design of our application. In Section 1.3, we state the specific problem we aim to address through this research. In Section 1.4, we summarize the importance our results hold. Finally, in Section 1.5, we give the structure of the remainder of the thesis.

1.1 Educational Technology

Educational technology, or the "study and ethical practice of facilitating learning and improving performance by creating, using, and managing appropriate technological processes and resources" [RMR08], is a large field of study involving psychologists, computer scientists, educators, and more. In general, e-learning (the application of educational technology) and m-learning (the application of mobile-device educational technology) have been found to be beneficial to students by improving: the effectiveness of concept communication, student motivation, and student engagement [Pap09] [CS12]. By now, there are countless applications available across multiple platforms aimed at improving student learning using the incorporation of clickers, smart boards, laptops, phones, tablets and other forms of technology.

One of the predominant issues in the field of educational technology is its own very dynamic nature. Technology is advancing and changing at a rapid pace, affording opportunities to create and analyze new models of e-learning. Current research has sought to consider the benefits and detriments of e-learning through studies on student progress and achievement across a variety of platforms. A commonly cited criterion for measuring progress is by measuring the technology's effectiveness (often determined by the amount a treatment group understands about a subject in a given time compared to a control group taught the subject in a traditional lecture-style approach). However, this effectiveness is subject to the educator's confidence in understanding when, how, and why to use technology for a given purpose and subject, in addition to selecting the appropriate type of device and software application.

This introduces a lot of variables into measuring the effectiveness that technology may offer when integrated into teaching methods and models. This makes the results heavily dependent on the environments in which applications are tested, and similar results cannot necessarily be replicated in different environments. This has already spurred criticism on the direction the field has gone, with many examples of experimental evaluations of software use within curriculum activities on a small scale, but an inadequate amount of research into some of the political reasons for educational technology not immersing well with traditional teaching in schools [Sel10] [RML10]. Research into the environmental issues surrounding the field then emerged, outlining issues that currently exist with principals, teachers, parents and students [Dav10] [IL10]. These problems may include the fact it is fiscally demanding on schools to be able to provide technology resources for every student, teachers are uncomfortable and lacking confidence in their ability to lead device-driven learning and troubleshoot issues when they arise, and there is a general resistance from teachers, principals and families toward e-learning.

1.1.1 Introduction to Learning Theories

Since the field of educational technology exists for the purpose of improving the learning process for individuals, it is critical to consider the major learning theories in educational psychology so that we can better understand the basis upon which the achievements of technology will rest. Human learning is a complex and multidimensional development. So, naturally, there are several theorized understandings of learning including behaviourism, cognitivism, and constructivism.

Behaviourist teaching styles are most prevalent in our current traditional teaching model, in which learning is described as a system of behavioural responses to physical stimuli. The effects of reinforcement, practice, and external motivation are of primary interest to psychologists within this field. The curriculum is based upon a breakdown of a finite knowledge base into smaller subsections, which are ordered in increasing difficulty. Students are passive, and rely upon practice, feedback and the teacher's lecturing abilities in order to learn. Afterwards, the learner is tested to evaluate where they fall upon a curriculum continuum [FP96]. Learning is achieved when the student properly responds to the presentation of a specific environmental stimulus [EN93]. Their progress is assessed by the teacher in part using responses to predetermined tests, whereafter they will continue in a linear fashion to the next subsection of that content area [FP96].

Cognitivism emerged as a response to behaviourism, as psychologists and educators began placing less emphasis on the observable behaviours of students as a representation of learning, and began associating it more with cognitive models of thinking, problem solving, and information processing. Cognitivist learning is believed to be internal, equated with passing through states of knowledge. Like behaviourism, cognitivism strongly emphasizes the role that environmental conditions play in facilitated learning. Thus, much like behaviourism the corresponding teaching style includes explanations, examples, and practice with corrective feedback. The difference in the learning theories lies on how the student is perceived. In cognitivism, the student is active, and their learning is defined not by their response, but how they perceive, analyze, and organize information in addition to setting goals and how they mentally plan the generation of a response. The focus of cognitive learning is not on improving the probability of a correct response, but instead on encouraging the learner to use the correct learning strategies.[EN93]

Constructivism describes learning as an "interpretive, recursive, non-linear building process"[FP96]. The cognitive development and deep understanding of a student remain the primary interests as opposed to their behaviour. The students are active in this learning style, always engaging and interacting with their surroundings in a variety of physical and social contexts. Technically a branch of cognitivism whereby both styles interpret learning as a mental activity, constructivism differentiates itself in several ways. Constructivists do not believe that knowledge is mind-independent; meaning is constructed as opposed to acquired. There isn't an objective reality for learners to strive to know, therefore their internal representation of knowledge is always subject to change. [EN93]. Learning is thought of as a construction of active learner reorganization, where learning is complex and non-linear in nature. This makes it difficult to build a corresponding curriculum, testing technique, or progress assessment metric for this learning style.

Stemming from constructivism is social constructivism which concerns itself more with the social environment in which learning occurs. Unlike core constructivism, social constructivists believe that meaningful learning is not an individual task, but rather a social task in which multiple students participate. Each member extends each others' understanding of the subject matter, contributing their personal meanings and considerations. This intersubjectivity created by a variety of cultural backgrounds influences the construction of knowledge.[Kim01]

With its appealing active learning style and its strong theoretical ties to interdisciplinary learning, there is undoubtedly support for constructivism, specifically social constructivism, within the classroom. Moreover, with modern technology becoming more powerful, accessible, and mobile it is popularly believed that technology can act as a platform for this learning, and there have been many attempts to do this. However, of these attempts and the countless applications available, many fall short in actually using the mobile technology in ways that extend learning past what traditional, behaviourist teaching methods offer [MO11].

1.2 Motivation

There is a foundation of research supporting the use of educational technology in pedagogy; similarly, there is foundation of research supporting the integration of social constructivism in classrooms. Regardless of the support for the integration of both fields (and for their use in conjunction with one another), there is a gap between the theory and practice for multiple reasons. Firstly, researchers have asserted technology will have no significant difference in effective learning if it is developed as an electronic duplicate of traditional teaching styles [SNM12]. In addition, teachers may not be comfortable in introducing technology into classroom learning if there is no clear goal or purpose to its use, or relevance to curriculum content. They may also be hesitant to learn techonology related skills in troubleshooting or data collection and analysis. There are also concerns with parents and principals favourably taking to technology integration.

Our research group has years of experience in computer science outreach initiatives predominantly at an elementary school level. We have used both traditional and technology-centred teaching mechanisms. We try to incorporate curriculum topics and real-world applications to the workshops we lead, to help reinforce what the students have already heard in class, or to offer new perspectives on their understanding of concepts. With experience in educational application development, we became interested in the fundamentals of student learning, and how teaching and learning methodologies may change with the inclusion of technology. The work presented in this thesis outlines our approach to developing an application to act as a platform for social constructivism and interdisciplinary learning.

1.3 Problem Statement

Given the theoretical support of the social constructivist learning theory for pedagogical purposes, there is a demand for the creation and analysis of novel applications for use in collaborative learning environments. These applications should enhance upon traditional teaching methods, offering innovative means for students to actively engage with learning content while enabling them to combine prior knowledge to customize their work.

To contribute to this field of research, we develop an iPad application for users to create and share their own gamebook called MacVenture. We outline the software design of the application, critique its advantages and shortcomings, and provide a guideline for its continued development.

1.4 Main Contributions

The main contributions to the area of educational technology include:

(i) A new iPad application for students to interactively incorporate language learning, graph concepts, and logic.

(ii) A novel example of heutagogy in classroom iPad application use.

(iii) A technique for offering a social constructructivist-style teaching opportunity for students, maintaining a learning goal for teachers to enforce, and an opportunity for data extraction on student graphs.

1.5 Structure of the Thesis

The remainder of the thesis is organized as follows:
Chapter 2 discusses previous work in educational technology and learning styles.
Chapter 3 introduces MacVenture by outlining its software design.
Chapter 4 presents some examples of the use of MacVenture.
Chapter 5 discusses the importance of learning tools such as MacVenture, in addition to addressing the strengths and weaknesses of the application.
Finally, Chapter 6 briefly summarizes the purpose and use of MacVenture, and outlines our intentions for future extension.

Chapter 2

Literature Review

There has been a lot of interest in the potential of iPad technology within the classroom since its release in 2010. A wide range of educational institutions quickly became interested in ways they could use the new technology to enhance learning. In this chapter, we will overview some of the research available in iPad educational technology throughout different educational contexts, applicable mobile learning (m-learning), and research reviews in the overarching field of educational technology and its use of social constructivism.

In Section 2.1 we will consider theoretical research done to create frameworks specifically for mobile learning environments. This will guide our consideration of what has been done before, and what other analysts consider in their evaluations for mobile learning. Section 2.2 will provide some insight into previous experiments and studies surrounding the introduction of iPads into classroom settings, while Section 2.3 will look specifically at work done to introduce constructivism and social constructivism into the classroom setting. Lastly, from a social constructivist perspective, we will consider some current applications created for learning in Section 2.4, and make some comparisons between them.

2.1 Mobile Learning Theories and Frameworks

There is a rich foundation of research that exists for learning theories. As introduced in Chapter 1, some of the core learning theories as described in Psychology include behaviorism, cognitivism, and constructivism. However, as technology has advanced, some psychological perspectives on technology based learning have emerged. In this section, we will overview two frameworks and compare how they relate to one another, to traditional learning models, and to software development.

Sharples et al. [STV10] propose a theory of learning for the mobile age, in which they specifically addresses the newfound mobility of learners and the idea that learning as an activity is varied among environments and times. Through their construction of a theory, they note the differences between mobile learning and other types of learning and outline criteria that mobile theories should address. Mobile learning begins with the assumption that learners are physically on the move; they learn across space, time, topics and weave in and out of accessibility to technology. Secondly, a considerable amount of learning occurs outside of traditional learning environments. Humans typically present information to one another in social contexts, or seek information and understanding when they encounter unknown objects or problems. Thirdly, theories should be based upon practices that have been successfully demonstrated. At this, Sharples et al. cite the US National Research Council's insights from research into educational effectiveness across ages and subject matter. To them, effective learning was defined to be: learner centred, knowledge centred, assessment centred, and community centred. They note how these findings broadly match the social-constructivist learning theory. Finally, their last criteria from which to base a mobile learning theory was to make considerations for the growing trend of accessibility to personal and shared electronic devices, not only in industrialized countries but within developing countries as well. These four criteria lend themselves to create a context through which the authors could compare "New Learning" to "New Technology". It draws strong parallels between the two in which personalized learning can happen on now personalized devices, learner centred tasks can occur on customizable applications, situated learning can occur on mobile technologies, collaboration is enabled through networked devices, and the notion that unpredictable learning desires can be accommodated by increasing technological accessibility. This work helps assert the potential mobile technology holds in collaborative contexts.

As with many learning frameworks and theories, where the authors center their focus greatly shapes the breakdown of the framework's components. Sharples et al.'s work concentrates on the communicative interaction between the learner and the technology to advance knowing using three cultural factors: Control, Context, and Communication. Control describes the party responsible for the learning content. This is usually managed by one person (the teacher), but it may also pass between humans and technology. Learners may control the pace and style of interaction with the content, while technology governs how information is delivered. Context is an ambiguous factor, incorporating several meanings depending on different theorists. It could be perceived as an isolated or emergent property of interaction from a technological perspective, or as the interaction of communities of actors with shared experiences. Regardless, it concerns the environment in which the learning occurs, whether they contain static or dynamic resources. Lastly, Communication is the relationship between learners' adaptation of their communication and learning activities to the structure and capabilities of technology. The example offered is if their workplace system incorporates email or texting capabilities, users will increasingly use these methods of communication for leisurous purposes after work.

This framework was carefully constructed from, and built upon ideas existing within other preexisting models. It stresses the factors surrounding the data or information presumably being learned. The parallels it draws between the current direction of learning and the direction of modern technology strongly motivates research in the field of educational technology and further drives us to consider the role the field could potentially play on a global scale.

A different pedagogical framework was developed and tested by Kearney et al. [KSBA12] to consider the full socio-cultural perspective of m-learning projects. Their resulting framework had three characteristics with corresponding subscales. “Authenticity” corresponds to the how users feel the task is useful and valuable to them. The subscales included “contextualization” and “situatedness”, where the former reflects the relevance and practicality of information to the user, and the latter analyzes the degree to which the task is embedded into the community of practice. The second characteristic is “Personalization” and its subscales “agency” and “customisation”. As the name suggests, personalization encompasses how the device allows the user to engage in personalized learning experiences given their immediate environment. “Agency” encompasses how the user is offered choices, goals, and self-regulation. The “customisation” subscale measures how the tool and activity can be tailored to meet different users’ learning styles. Lastly, “Collaboration” can be achieved by making connections to peers and resources via the mobile device. It includes the subscale of “conversation” which judges the the activity’s inclusion of rich dialogue, and “data sharing” which measures the networking of data, especially user-generated data.

Immediately, we notice some similarities between the dialogue used in both Kearney’s and Sharples’ frameworks, including the terms “context” and “conversation”, however, their interpretations are varied. Within Sharples’ framework, the Context and Conversation helped define how the user and technology interfaced with one another. They direct the analyst to consider learning as the “process of coming to know through conversation across continually re-constructed contexts”[STV10]. This ongoing exchange of communication to and from the learner, with their environment offering dynamic or static knowledge sources to support knowledge construction is very reminiscent of the social constructivist learning perspective. If we consider Kearney’s framework, contextualisation and conversation act as subscales of Authenticity and Collaboration. We can see how the socio-cultural approach greatly increases the consideration of the user themself in the learning process. It is worth noting that through developing one of their framework characteristics as Collaboration, a heavy consideration of their learning opportunity comes from the information exchanged through other users and devices. As such, this framework also poses itself to consider applications and devices in a social constructivist way. Whereas the first framework is a more objective analysis of the system's interactions, the second framework is a more subjective analysis of how the user perceives the system could serve them. Neither are more correct than the other; they are simply different views on human-computer interaction.

In short, even from the different perspectives of these frameworks, mobile learning theories need to accommodate potential users' desire to develop knowledge through their interactions with others. To hold the belief that knowledge is constructed not only through the experience of the user, but in sharing experiences with other users as well, is to tend towards defining learning as a psychologically social process. Thus, regardless of the framework one selects to evaluate their mobile application or device, their development process should tend toward enabling information and data exchange between users for effective learning to take place.

2.2 iPad Learning

Within this section, we consider the iPad as a learning tool. We review studies in which teachers and students have actively used it to enhance learning within the classroom, and note their feedback and considerations on how to better employ the use of iPads as an educational platform.

To begin, let us consider the work done by Harper and Milman [HM16] who provide a review of the literature from 2004 to 2014 of one-to-one technology use in classrooms. They provide a concise summary of the results noted in empirical studies where students each had access to individual devices (a 1:1 ratio). Of the 46 total articles reviewed, 35 considered laptop or netbook studies, and 12 considered tablets in their analyses. They extracted the trending themes throughout the studies: effects on student achievement, changes to the classroom environment, classroom uses, effects on learner motivation and engagement, and challenges to classroom integration. We begin by summarizing applicable points on each theme.

On the topic of student achievement, reviews were mixed. However, the majority indicated that 1:1 technology provided students with some achievement-related benefits. On the topic of changes to the environment, they begin by addressing changes in students' learning experiences. Classrooms with 1:1 laptop access and traditional classrooms had different organization. Those with the technology experienced more group work to encourage collaboration, as well as more frequent and more effective communication between peers.

Concerning differentiated instruction, multiple studies of various devices support that 1:1 integration increases the meaningfulness of personalized instruction. There are also changes necessary in the teaching models recommended to accompany 1:1 instruction, with researchers supporting constructivist instructional principles and citing improved math and reading achievements when doing so. Harper and Milman note that not all teachers will have a sufficient understanding of constructivism or how to employ it when teaching with 1:1 devices. On that note, we can see that if an application were to be developed that inherently uses the constructivist methodology within it, it would support that learning independent of the teacher's understanding of learning theories.

On changes to the classroom environment they make note of cooperative learning. On this aspect, studies are mixed, with some noting that the technology seems to drive independent learning, and others asserting it encourages collaboration. Of the tablet-based technologies cited, it seems that the tablets improve communications between students and their peers.

On the subject of motivation and engagement, many articles reported promising results, citing impressive responses from students on both accounts. One school even cited a decrease in disciplinary actions over a 3 year period with the introduction of a 1:1 laptop program (although it is noted that more research would be required to link the data to the student engagement responses).

In classroom uses, the studies show that many devices were simply used for web browsers and word processors and on the odd occasion as facilitators of drill and practice routines. In addition, studies note that increasing accessibility to classroom technology does not necessarily mean increased use. As noted, this may be due to external factors like busy curriculum demands on teachers.

Lastly, Harper and Milman note the challenges to the integration of technology as indicated by their selected studies. It appears that most students are more likely to have favorable expectations of technology integration if they have had previous experience with 1:1 education techniques. Teachers also have concerns regarding the effects that the implementation of 1:1 techniques will have on their classroom environments and that they have apprehension in leading activities using them whether they are comfortable or not with their personal technology use. Many teachers identified teacher training and professional development as necessary measures towards introducing a 1:1 environment, while describing the learning curve in exploring the use of these tools as quite steep.

Some researchers have classified applications on the market to better understand what is available to students. Murray and Olcese [MO11] consider the potential of iPads in K-12 classrooms by looking for applications that fostered learning opportunities that traditional teaching could not offer. To do this, the authors reviewed educational applications available on the market specifically for the iPad and its larger mobile screen size. Over a period of three months, they tracked newly released applications and sought to understand and categorize the learning style the developers had used. They categorized the 315 applications considered under headings of "tutor" (112 applications), "exploration" (79 applications), "tool" (73 applications), "communicate" (38 applications), and "collaborate educational technology" (15 applications). They categorized the applications using the questions:

(i) *Tutor*: can users decide or choose information to learn or interact with?

(ii) *Exploration*: can users add or create information?

(iii) *Tool*: can users utilize the application as a tool for a greater purpose?

(iv) *Communicate*: can users collaborate with other users of the application?

They found a majority of the applications they analyzed did not extend the functionality of an activity through utilizing the iPad's abilities. They also noted that a vast majority of the applications considered were lacking any kind of collaborative component. They conclude by stating that their "review of applications written to run on the iPad and other iOS devices suggests that the innovations Apple has brought to market are not being taken up by the software development community". Hence, they did not believe the iPad would become a revolutionary tool in teaching. The "lack of collaboration capabilities underlie this point, as do the overwhelming number of application[s] that are simply drill and practice or focused on delivering content for consumption, not creation or re-use." Through this, they were explicitly remarking that applications in support of behaviorist learning can be easily duplicated from phyical pen and paper activities that have students repeatedly practise some problem solving technique. In contrast, they were looking for applications that would offer a creative thinking space for users to create and share their learning experiences within.

Interested in the adoption and use of iPads in primary schools, Henderson and Yeow [HY12] presented a 2012 case study from within one of the first primary schools in the world to adopt the iPad as a teaching tool. They acknowledge that many educational technologies have taken a behaviorist approach to teaching, while educational teaching theories support constructivist learning. The iPad's release was exciting for educators as it offered the mobility for group work in classes, and the technological capabilities to share and exchange work. This supports social constructivism if the application encourages students to create or construct their knowledge and then share, review, and engage in other students' work. They note the particular advantages of mobility, engagement, and collaboration, but note there are issues with the use of iPads as well. Choosing appropriate applications from those available may be difficult, and schools need a process to assist in these decisions. Additionally, they note that teachers may be worried that students would get distracted from their designated task. In general, teachers found the iPads make "a very useful tool for education".

In their pilot study of the use of a potential tablet app called OurStory, McPake and Stephen [MS15] sought to investigate the relationships among educational theory, designed artefact and practice. Over a period of four weeks, they lent iPads out to preschool practitioners teaching Gaelic in Scotland, but gave no direct instruction as to how they should incorporate the devices into their teaching. The practitioners ended up taking a large number of photographs of familiar playroom objects and activities. Using these images, they created storyboards to show how the images could be grouped together and shown in sequence. Additionally, they were able to add captions and record audio to encourage students to engage more with the stories. The practitioners began to think about how students could take photos and create their own stories. However, given their age, students ended up simply compiling sets of photos together in a theme while neglecting any construction of narrative. When providing feedback, practitioners' beliefs tended toward believing performance tasks were more effective in language learning than authentic communicative practices. In other words, they favoured a more behaviorist approach to learning as opposed to a constructivist approach. From this, we can gauge that the effectiveness of iPad educational technology may also be dependent on age, as Henderson [HY12] as well noted the iPad's success to be more apparent in senior grades (ages 9 to 12) as opposed to junior grades.

Also concerning preschoolers, Couse and Chen [CC10] did a case study on 41 children (ages 3 to 6) assigned to make self-portraits on a drawing application with a tablet. They sought out to include more empirical based research on educational technology, and included interviews with teachers afterwards to gather feedback from instructors and students alike. They make several observations of their findings. Firstly, students were excited and comfortable with using a tablet, and quickly grew accustomed to the drawing software. In addition, any presence of a computer in each of the students' homes seemed to hold no bearing on how they grew acclimated with the technology. They also found that younger students spent less time on the tablets than the older students did, supporting existing research that engagement with technology increases with age, and the older students actually held more of a preference in using the tablet for writing over traditional pen and paper. The children were enthusiastic about sharing their creations with their peers, which supports the idea that educational applications should be developed with collaboration mechanisms.

In another analysis with a Grade 4 class, Hutchison [HBSC12] sought to investigate the viability of using iPad applications to aid in her students' literacy learning. This process included analyzing multiple applications and features of those applications which the teacher and the 23 students found particularly useful. The author notes that

> Apps that appear promising for literacy purposes are those that allow users to type or write on top of printed text or other backgrounds, to record audio for a response, to add pictures from a photo library, to insert symbols and stamps, and to graphically organize responses in virtually limitless ways. [HBSC12]

The teacher in this study agreed to incorporate iPads into her instruction on a daily basis for a period of three weeks. She often had students work in pairs or in small groups and noted that they were very engaged in using the devices. The iPads enabled creative ways of responding to goals and challenges, while offering unique affordances a paper-based activity could not. For instance, in a mind-web style application, the students did not feel restricted by the boundless virtual paper as they might have by physical paper, enabling web designs that might not otherwise have come to fruition.

The studies we have considered thus far have been centered around research surrounding elementary school students and their use of educational technology. Student engagement and perceived usefulness seems to improve with age as students move from preschool to upper level elementary grades [CC10], but interestingly enough, this trend may not continue to be true for young adults. In Culén and Gasparini's report from two pilot studies [CG11], they compare the acceptance of technology between a study of 40 university students in a Geology class, and 26 Grade 4 elementary students. The university students had a general non-accepting attitude towards iPads as a learning platform after a term of schoolwork with their own designated device. In short, they believed it would be too cumbersome to learn a multitude of applications properly in addition to their existing workload. They had difficulties using it to take notes given the minimal desk space offered with lecture hall seating. Their professor was unwilling to incorporate the iPad's use into his teaching as he had an established course structure and teaching method he did not want to stray from. The university students also encountered some technical challenges that may be contributing factors to the unenthusiastic response. The students often wanted to navigate between multiple documents and applications for academic purposes, when the iPad restricts the user to only one. They additionally had problems viewing images and downloading files.

The schoolchildren of the other pilot study however, enjoyed many of the benefits previously mentioned in other studies: they found the iPad engaging, they enjoyed sharing the iPad among their peers, and they enjoyed reading and researching topics at their leisure. The zoom capability was noted as one of the strong proponents for iPad e-Book reading. Students were often found to be continuously zooming to their preferred reading size during activities.

2.2.1 Benefits

Many of the most common benefits from iPad education are noted through the analysis done by Harper [HM16]. There is an obvious interest in harnessing the potential of iPads as educational devices, as they have demonstrated slight grade enhancement, increased on-topic and effective collaboration between peers, increased motivation and engagement with academic topics and goals, and improvement in the quality of discourse with the teacher. However, these benefits come with the selection of the proper context, appropriate audience, and the training and comfort of the teacher.

Technology in the classroom has benefits outside of its designated use. Henderson and Yeow [HY12] note how students also regularly used the iPads for other purposes than the assigned educational applications. They browsed the internet for research, connected them to projectors for presentations, or used e-books to view electronic copies of their textbooks. Of course, this is double-edged as it may also lead to complaints of student distraction from tasked assignments.

2.2.2 Existing Issues

After an extensive literature review, the field of m-learning seems to have some common issues. The first issue is that many of the software application designs entirely lack constructivist components. If the software is meant to act as a platform within which students can explore, immerse, and create, then the applications must offer much more flexible functionality than posing as a simple blackboard for content consumption. Another issue is setting an appropriate scope for the application to exploit constructivist benefits. Given an application which focuses on one subject matter, like mathematics-based electronic cue cards, the application loses the capacity to challenge the learner to apply concepts in an interdisciplinary manner, unless the software is explicitly changed and updated to do so on a routine basis. Similarily, if the scope is set too wide, students lack clarity in understanding the purpose of the activity, the problem they are being asked to solve, or how they should begin approaching a solution. With that degree of confusion, it is much more likely students will begin getting side-tracked by their peers or other software applications, which will contribute to overall classroom disruption.

Henderson and Yeow [HY12] comment on how including educational technology into curriculum coverage has its administrative challenges. They note how the school in their study had a booking system in place for classrooms to request the iPads since they are expensive to replace, and therefore they need to stay organized with schedules and management. They additionally note the need to update system software on occasion, that there are incurred costs through protective gear for devices and possible data plans or costs affiliated with the use of wireless internet. They note that distractions are always going to be an issue when offering students multi purpose devices, but by maintaining strict rules, including the requirement that screens stay "open and visual" to the teachers, they can maintain classroom order and keep students in focus.

It is important to consider these issues while developing educational software applications, as they can usually be corrected using certain aspects of the software design. Whether this is reconsidering the platform of deployment, considering alternative methods of interaction and collaboration, or introducing new software objectives to instruct and direct users, there are ways we can address the environmental issues through the development process.

2.3 Constructivism in the Classroom

The idea of integrating constructivist tactics into education is far from new. Scheer, Noewski and Meinel [SNM12] state "Advantages of constructivist learning have been well-determined through theoretical findings in pedagogy. However the practical implementation leaves a lot to be desired". They discuss some of the issues in the field contributing to this lack of integration, including the challenges educators face. They claim there is a missing link between the theory and practice of pedagogy science, and that Design Thinking as a team-based learning process will help bridge that gap. Design Thinking was the name given to the six-step problem solving process they define within their work. They list the steps as: understand and observe, synthesis, ideating, prototyping, testing, and iteration. Their study concludes there is an improvement in the classroom experience for both teachers and students when using Design Thinking after having received feedback from a case study with high school students in Germany, and that this aid in facilitating constructivist learning will help foster 21^{st} century skills. These 21^{st} century skills refer to:

(i) critical thinking and problem solving

(ii) collaboration across networks and leading by influence

(iii) agility and adaptability

(iv) initiative and entrepreneurialism

(v) effective oral and written communication

(vi) accessing and analyzing information

(vii) curiosity and imagination

These skills have been identified as crucial skills for individuals to have in order to be effective workers in our rapidly changing society, and also ones that can be built through holistic, constructivist teaching.

In 2013, Cochrane, Narayan, and OldField critiqued eight m-learning project case studies that had been presented in literature [CNO13]. Four of the studies were m-learning projects, and four were iPad projects. They address an issue that had been brought up throughout literature as the "no significant difference phenomena". It asserts that there is little to no measurable benefits to using educational teachnology as opposed to traditional instruction. Cochrane et al. note this as an unfair assessment given that many practitioners simply used the technology to replicate traditional teaching methods. They assert that future research needs to be conducted on applications that take advantage of the pedagogical affordances unique to the iPads and other m-learning devices over what is available by traditional instruction.

In 2014, Thinley et. al [TGR14] overviewed how iPads and mobile learning (m-learning) are being used in higher education. They claim that applications that are available have "demonstrated behaviorist, constructivist, and collaborative perspectives of learning theory", but that effective learning needs both teachers and learners actively participating in the process. Therefore, there is a "need for applications that create effective learning environments which are learner-centered, knowledge-centered, assessment-centered, and community-centered", and that these results match the social-constructivist approach of learning. They use the "Conversational Framework" developed by Laurillard in 2002 as a test to measure whether available applications were reaching their full pedagogical potential. They found that of the technologies they considered, all were merely digital adaptations of the course content that was previously available, and iPads need to be adapted as a tool that supports active learning pedagogical approaches. They outline a taxonomy of educational apps with five classifications as seen in Table 2.1.

	Application Category	**Description**	**Learning Theory**
1	Content consumption and creation	Help learners to organize their learning materials	Some behaviorist learning theory with use of quizzes
2	Content delivery	Used to make lecture delivery and presentation more dynamic	Constructivist learning theory
3	Collaborative and interactive learning	Encourage any kind of communication among teachers and students	Behavourist learning theory and elements of social constructivism
4	Course management	For managing and organizing courses more efficiently	Not applicable
5	Teaching and learning	Support teaching and learning activities	Not applicable

Table 2.1: Application classification system by Thinley et. al [TGR14]

From their analysis, they assert that "universities need to develop applications that make the learning environment learner-centered, knowledge-centered, assessment-centered and community centered. This learning environment would then match the social-constructivist approach to learning, where students play an active role in their learning, and teachers and students collaborate to facilitate knowledge construction". They end this discussion with the clear point of "to make the most of the tablet, there is a need for educational applications that can capitalize on the benefits of effective learning pedagogies".

2.3.1 Learning from an Instructional Design Perspective

One paper that resonates well through the foundation of research in learning styles and their implementations within software applications is an overview provided by Ertmer and Newby back in 1993 [EN93]. Although an older paper, it was created to familiarise designers with the theoretical background of learning theories to better understand how to develop applications to facilitate the teaching approach they were interested in. Most interestingly, they discuss the process in which we learn not as defined in any one theory in particular, but as a continuum of definitions as our familiarity grows. As students move from learning the basic facts, rules and operations into thinking like a professional, they become able to extrapolate information and solve problematic cases. This in turn precedes an ability to develop new forms of understanding when standard forms fail (reflection-in-action). That is,

> a behavioral approach can effectively facilitate mastery of the content of a profession (knowing what); cognitive strategies are useful in teaching problem-solving tactics where defined facts and rules are applied in unfamiliar situations (knowing how); and constructivist strategies are especially suited to dealing with ill-defined problems through reflection-in-action.[EN93]

Thus, one can imagine that by imploring the introduction of social constructivist methodologies to a classroom is not to say that strategies to facilitate other learning strategies should be suppressed, but rather that activities encouraging students to actively create and share ideas using their newfound knowledge is the final step in a different learning approach that is often overlooked. There is a need for the design and implementation of technological applications that can act as a collaborative platform for this step.

2.3.2 Benefits

The benefits of using a social constructivist approach follow mainly from the benefits employed by the theory, but any additional benefits from a technological perspective are difficult to ascertain. Even following from Harper's compilation of support for constructivism with technology [HM16], it is still difficult to find applications that offer themselves as creative platforms for creating and innovating while offering multimedia options for students to construct and share creations with peers. When more applications supporting this style are available, we may begin to empirically analyze that they encourage students to problem solve and build in an interdisciplinary manner, that they begin to optionally construct new projects with peers at will, that their engagement with their work extends past their working schedule, and that their ability to receive and offer constructive feedback improves. In this way, perhaps we will begin to move our education system to better prepare individual and collaborative learning that is much more conducive to industry needs.

2.3.3 Existing Issues

Some of the criticism regarding the nature of constructivist learning in the classroom stem from teachers who feel there is a "constant feeling of uncertainty and chaos, as well as a lack of process to follow" [SNM12]. There are also concerns with how the technology prohibits true constructivism as it may force construction of concepts into a particular symbolic form (word, graph, picture) [Sal98] altering and redirecting the student's original vision.

This criticism is important for future developers; it highlights specifically where the bridging gap between constructivist theory and its implementation in academia fails. The research exists supporting the bond between mobile technology and social constructivism, so the market needs more innovative approaches to satisfy the learning style that psychologists have proposed but with ease of use, direction, and support for teachers to effectively host.

2.4 Existing Applications

In this section, we will overview some existing applications that use social constructivist methodologies. Our first two applications, *Classroom Presenter* in subsection 2.4.1 and *Group Scribbles* in subsection 2.4.2, are highly applicable to our research as the technologies are used in interactive means within a classroom setting. We also present *StudyBlue* in subsection 2.4.3 which is at heart a knowledge creation and sharing platform. Although not a constructivist style application, we consider *Touchable Earth* in subsection 2.4.4 for its innovative approach to content sharing. Lastly, we discuss the similarities and differences between these applications and consider the implications of their use in subsection 2.4.5.

2.4.1 Application 1: Classroom Presenter

Classroom Presenter is a Tablet PC-based interaction system that supports collaboration between the instructor and student for electronic slideshows regardless of their physical proximity.

> Both the instructor and the students are equipped with tablet computers. At various points during a lecture, students are asked to solve a problem or answer a question. In response, students write their solutions on the tablets and submit them wirelessly to the instructor. The instructor can view all responses, select one or more to display to the class, and annotate responses with ink as they are being displayed. [AAC+06]

With the incorporation of a video streaming software, *Classroom Presenter* has been used to present communal lectures between several universities worldwide, allowing for the students to view the responses and perspectives of students from other countries and communities. While certainly increasing the active learning component for students, there is still minimal interaction and coordination of material between the students themselves.

2.4.2 Application 2: Group Scribbles

Group Scribbles is a software platform developed by Roschelle et al. [RTC+07] that coodinates the use of technology among students. In *Group Scribbles*, students have a *Scribble Sheet* on their tablet PC web browser which is a virtual sheet for them to quickly illustrate images or jot down responses. Students have the option to create more Scribble Sheets and arrange them on their own private boards. The private boards allow students to organize their thoughts and arrange responses before pushing them to a public board. On the public board, users can see their submission alongside their peers and can collectively arrange the Scribble Sheets in different manners. This means that “while individual sheets express individual thoughts, the entire board expresses collective ideas”. The platform as a whole is based on the time-sharing of the public platform as required by a coordinated, distributed computing system. The authors post several examples of how the platform can be used in different contexts to enhance different teaching strategies. One example poses the question of asking students to label fractions from smallest to largest on the public board, while another asks the students to submit equivalent fractions to the public board.

Group Scribbles is a great demonstration of social constructivism in the classroom, where its repository style architecture enables the contributions and collaboration of every student. Their final product focuses on knowledge construction, active feedback, and engagement.

2.4.3 Application 3: StudyBlue

StudyBlue [STU] is a learning platform available on desktop and mobile allowing for the creation and exchange of flash cards, study notes, study guides, testing mechanisms and progress feedback. Students can add material to groups or work individually, and there are teacher-specific accounts that can distribute learning resources to their students. Users may add other students into a linked set of contacts, and track their progress through graphical representations. The application also suggests areas in which the user may be struggling based upon their testing feedback. Flash cards are a staple in behaviorist reinforcement mechanisms and memorization tools. However, by moving the flash card creation responsibility to the student, this application begins to segway into constructivist methodologies, and specifically social constructivism given that users may share content amongst themselves.

2.4.4 Application 4: Touchable Earth

While not explicitly a constructivist application, *Touchable Earth* [Tou] offers portrait photographs and videos of children from various parts around the world that the application's creators specifically visit to create content for. Users can learn key facts and daily insights relating to the lifestyles of other similarly aged children from different cultures. This acts as a content consumption tool, the knowledge transfer is unidirectional, and so clearly the application is behaviorist. However, the topic itself holds a lot of promise with social constructivism. The content is delivered and at least in part created by other children, expressing the knowledge sharing to users as if they were classroom peers. Should the platform ever expand to offer interaction between the students, and the ability to create and upload user content, it holds the potential to become a great social constructivist application for students learning social sciences. It would offer immersive and interactive means of understanding cultures and communities through the eyes of those who compose them.

2.4.5 Similarities and Differences

Classroom Presenter's structure was actually considered in the development process of *Group Scribbles*, since they have similarities in context and architectural style. Both applications are responsible for retaining engagement through lecture delivery by making the process more interactive, and allowing aspects of the subject content to be be guided by the teacher as a facilitator, but built communally by the students as active learners. As Roschelle et al. note about *Classroom Presenter*, it does "not support coordinated use of the technology among students" [RTC+07]. In this way, the software itself embraces constructivism and potentially scaffolding, but not social constructivism.

By contrast, *StudyBlue* has social constructivist components while targeted at students working asynchronously from any spatial proximity. From a social constructivist perspective, just like *Group Scribbles* and *Classroom Presenter*, it compiles responses from multiple users into the shared knowledge resource base. These users may generate their knowledge using any resource they choose. However the information being compiled is built into a format that encourages memorization and correct signal-response behavior. In this sense, the knowledge is built for behaviorist learning, and caters the knowledge acquisition and creation phase to also cater to what will ultimately be deemed correct in the eyes of their particular instructor or tester at that time. Because of these considerations, it could be argued *StudyBlue* promotes behaviorist, not constructivist, learning.

The final application considered, *Touchable Earth* has already been discussed to have great potential for a social constructivist application although it currently is not structured as one. The content itself however, is open ended as encourages learners to seek out knowledge from a set of video references. It could open itself to contributions from many perspectives from within communities, allowing users to read and internally recreate their own understanding of other places and cultures.

2.5 Conclusion

In this section, we overviewed the current status of educational technology, specifically in regards to the use of iPads within the classroom. We saw that many mobile learning theories include collaborative aspects as supported by social constructivism, and that researchers interested in the benefits of educational technology in the classroom also heavily value the ability for students to collaborate. Although the current field of learning research stresses social constructivism, there exists a gap between academia and the products being developed to support this learning theory. Educational applications have not been utilizing software devices to their fullest potential, and the market is populated with a great deal of behaviorist reinforcement applications that do not offer any unique learning opportunities past what has been traditionally available.

This overview of literature has framed the context for our research. There is a need for applications to act as open-ended platforms of learning, in which students can build projects catered to the subject of the teacher's choosing. They need to have some structure, in that there is a specific goal for the students to achieve, without being so rigid as to restrict the style in which the students wish to communicate. Students should have the ability to share their work, as well as interact with others' creations. Finally, the platform should allow teachers to electronically compile relevant information for the purpose of grading and statistics.

Chapter 3

Software Design

In this chapter, we introduce and detail the design of the MacVenture application. In Section 3.1 we overview the purpose of the application and our justification for using a gamebook-style format. In Section 3.2 we describe the application, the assumptions, the requirements, the objectives, and describe the architecture. In Section 3.3 we provide an application walkthrough to detail MacVenture's functionality. In Section 3.4, we discuss the perceived benefits of using the application in a variety of ways.

3.1 Rationale of the Gamebook Creation Premise

Gamebooks are printed fictional works that consist of multiple storylines. The reader will encounter decision points throughout the text and their choices will determine which branching storyline they will engage with next. Some popular examples include the *Choose Your Own Adventure* novels published by Bantam Books and *Find Your Fate* including books by R. L. Stine. Stine later created several of his own popular gamebook series like *Give Yourself Goosebumps*.

Within the field of education, the gamebook-style format was quickly adopted into *TutorText* in 1958 which was a series of nonfiction interactive textbooks. This style of learning was dubbed “Programmed Learning” by behaviorist B. F. Skinner. These books were reinforcement techniques that supported learning in a behaviorist manner, but additionally contributed to the foundations of open learning and educational technology as a whole.

Gamebook-style formats are appealing for multiple reasons. Firstly, they generally have an overarching theme or topic for the learner to explore. This provides a clear purpose to the user as to why they should engage with the activity. They also clearly defined branching questions and their possible responses. Users understand when they need to make a decision, and what their next step is when they have chosen a response. Finally, the branching conditions force the user to be active; a quality both behaviorist and constructivist learning theories support.

It is clear as to why gamebooks are behaviorist and not constructivist. The information is still presented in textbook format. Similar to lecture style instruction, textbooks have the user passively read and absorb information before making active checks on whether they understand the content properly. While the active checks are appealing, they can be improved from a constructivist standpoint by not only having the user be able to run through the gamebook, but also create the gamebook. This is what MacVenture was built to do; it acts as an open-ended platform for the user to create their own gamebook. By doing this, the user is tasked with understanding the content they include, and the degree of complexity in which it is included.

Our purpose is to build a social constructivist style teaching application, while improving upon some of the issues and criticisms previous applications have received. We have decided to build a gamebook creation application, as it will encourage students to not only understand, but communicate how responses to decisions take the gamebook reader upon different branching paths. How they come to learn this information may be explored at the time of their gamebook's creation, but by providing a purpose for learning it the application provides a definitive goal to the user.

3.2 MacVenture Design

In this section, we will outline the software specifications for MacVenture. This includes the description, assumptions, requirements, objectives and the resulting software architecture.

3.2.1 Description

MacVenture is an iOS application designed to be used in a classroom setting. Each student (or group of students) runs the MacVenture application on an iPad they have been assigned. Designed to be an open-ended platform for innovation, MacVenture allows users to create gamebooks, save their creations, play through their creations, send their game to peers to play, and receive others' games to play through. The application is targeted towards use in elementary schools.

The application presents the user with a screen with which a user can tap and interact with to create their own graph. This graph models their gamebook design. The nodes in the graph represent pages in the gamebook (or as we call them, “Places”), the edges in the graph represent the relationship between one page and another page (we have called “Ways”). The Ways may be unidirectional or bidirectional, indicating that some pages in the gamebook can be returned to and others can not. The Ways can also be locked, and require the gamebook reader to tap on certain highlighted words in the story (termed picking up “Keys”) in order to continue. A more detailed look at the gameplay can be analyzed in Section 3.3.

MacVenture is designed to be eventually integrated into a system involving a secondary application for the teacher’s use. The teacher’s application will be designed to send information to the student applications in the form of a vocabulary list, and compile data from the student’s applications for grading purposes and running analytics. The expected benefits and plans for future work on the teacher’s application can be reviewed in Sections 3.4 and 6.1 respectively.

3.2.2 Assumptions

Due to the resources available to our research team, the application had to be built in the iOS framework with a deployment target of iOS 8. The application was designed for the iPad, and specifically used on the iPad 2 and the iPad mini 2. Devices must have at least one form of networking enabled to support sharing.

3.2.3 Requirements and Objectives

In accordance with the idea that the application incorporate social constructivist methodologies in addition to addressing issues previously detailed, the software must adhere to the following requirements:

(RI) The application must allow the students to create an electonic gamebook.

(RII) The application must allow teachers to customize vocabulary goals for students.

(RIII) The application must allow users to convey information in a variety of ways.

(RIV) The application must be easy to use by elementary school students.

(RV) The application should be able to save multiple gamebook creations on each device.

(RVI) The application should allow easy editing and reconfiguration of gamebook entries.

(RVII) The application must allow students to send and receive games to peers to play.

(RVIII) The application must be able to package data to send to a teacher application.

To satisfy our given requirements, we developed an outline of our tasked objectives. We wanted to develop an application that would allow the students to create a gamebook in a graphical representation. By mapping the gamebook's design to a graph, we are able to not only implicitly introduce elementary students to elements of computer science graph theory, but we also provide a simple interface within which to configure and create their stories. In the graphical representation of the game, each game page is represented by a node. These nodes will be customizable by a corresponding picture, title, and text. This gives students different ways to customize material, examples of which can be seen in Chapter 4. The graph creation screen will start with a undeletable beginning and ending node. These nodes represent the source and sink of the graph. We decided to automatically define a source and sink for several reasons. Gamebooks always have at least one end. For readers, this end makes a goal to work towards which is a source of motivation, even in the existence of graph cycles. Frequently in our outreach activities, the students will create their stories iteratively by creating some pages in the story, playing through the gamebook, then returning to the creation screen to make edits and changes. Usually, it is through this process they begin to understand the importance of the existence and direction of the graph edges. Once they understand how the graph can be created to incorporate both the given start and end, they begin to become more creative in offering customized alternative endings. From a graph theory perspective, this may be the first time they come to understand the importance of connectivity by building the existing disconnected graph into a connected graph with no unreachable vertices.

The application should also have a tutorial mode for learning the game mechanics including making a new node in a graph, and connecting nodes to one another, and changing them from bidirectional to unidirectional and vice versa. Finally, the application should have the ability to share a game with other nearby devices via WiFi or Bluetooth. As the teacher's application is not yet developed, teachers should be able to verbally tell students vocabulary words they would like them to use as part of their story. Students should be able to store these words as Keys in their game. These Keys will be highlighted throughout Place descriptions as the student develops their story, so they can easily identify which words they have used already.

3.2.4 Software Architecture

In this section, we will discuss the software architecture of MacVenture, and how the design satisifes the structural requirements of our project. The main architecture style falls within the interaction-oriented software domain: specifically the presentation-abstraction-control (PAC) style. This architecture supports multiple agents (devices) within the system, each with their own PAC components as seen in Figure 3.1.

Each device has a presentation component that handles the views; it allows input and output exchange via the user interface. It also has an abstraction component in which MacVenture stores all game information using the CoreData framework. Places, Ways, and Key values are stored as entities with applicable relationships. The data is passive. Upon opening the application, the applicable controllers will pull the information previously stored and send the information to the view to create the graphical representation of it for the user. Lastly, the control encapsulates the UIViewControllers within the application. It also manages the manipulation of data and the communication between devices.

Using this architecture has several benefits which align with our objectives well. It supports multitasking and multiviewing, which is especially important for game sharing functionality. It also supports agent extensibility, which handles the addition of more student devices in the classroom. Lastly, the coupling between the agents is loose, ensuring changes in one agent do not affect the others.

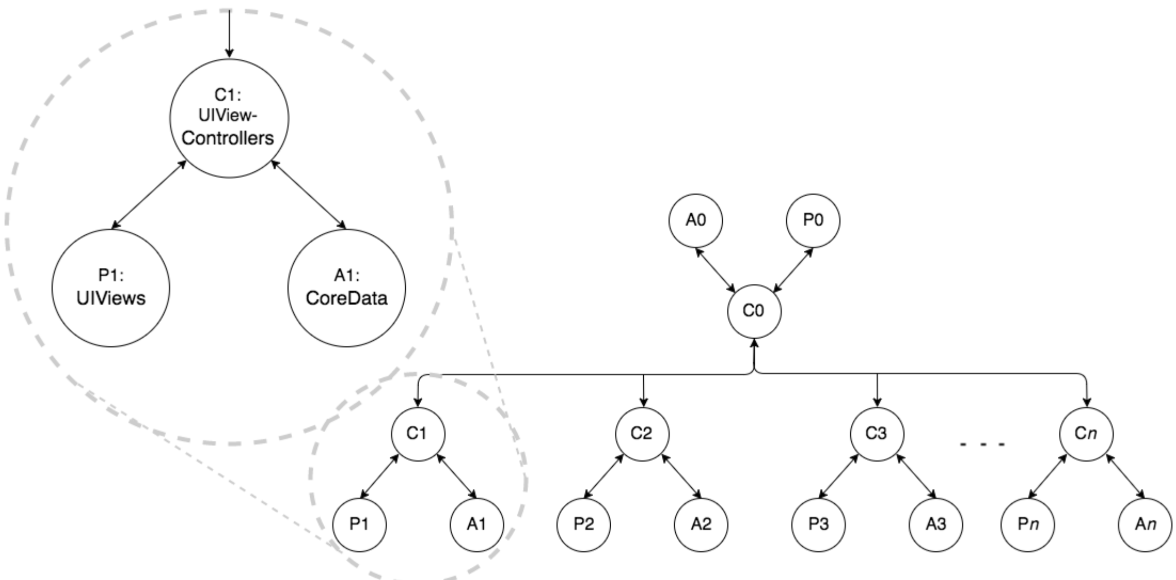


Figure 3.1: Multiple agents in PAC

We can see how the architecture maps to the application's analysis class diagram, as shown in Figure 3.2. Central to the design are the multiple controller classes which could be collapsed into the single PAC control component. Attached are the multiple entity classes which compose PAC's abstraction, and the boundary classes which compose PAC's presentation. Note that as expressed by the architecture style, the entities and boundary classes are loosely coupled, as the controller classes actively manipulate and move information between both.

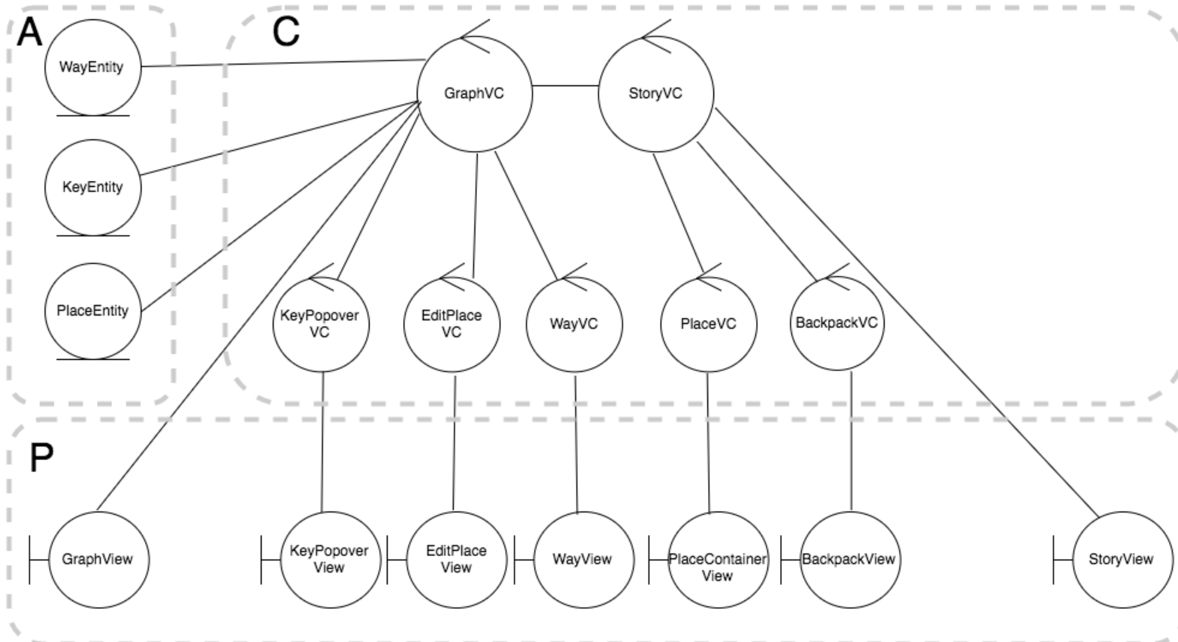


Figure 3.2: Analysis Class Diagram of MacVenture

3.2.5 Refinement as client-server architecture for device communication

An important factor to also consider in the design of the application's architecture is the communication between devices. Using Apple's Core MultiPeerConnectivity framework, devices are able to discover and interact with other devices. Between every interaction, a device will act as the peripheral agent (one that contains data needed by other devices), and as the central agent (one that uses the information sent by peripherals) [Cor]. The design of the framework's communication reflects the client-server architecture as each central agent acts as a client using the broadcasted information, and each peripheral device acts as a server processing and sending information to the central agents. In our design, each device actually acts as both a central and peripheral agent, as students may create and broadcast their game, or receive others' games to play through.

3.3 Application Interface Layout

MacVenture actually has quite a simple set of interfaces as seen in Figure 3.3. From the main menu the user can select the "Tutorial" or "About" buttons to launch popovers. The tutorial explains the concept of a gamebook quickly before teaching about the mechanics of using the application. The About page will inform the user about our research team. From the "Play" button followed by a game slot selection, the user is taken to the main screen of the application to begin creating their story.

The main screen of the application is a white background with two existing pages of the story already created named "The Start" and "The End". Each page is represented as a node in the graph, which is currently depicted by an illustrated fish icon set as the placeholder. The Start and The End act as the source (origin of the graph traversal) and the sink (final state of the graph traversal) of the story. The user can tap and add new pages to the story, and drag new connections between pages. The connections are represented as edges in the graph, which are currently depicted as blue lines with a lock in the center. These connections have the ability to be unidirectional or bidirectional. Thus the reader may traverse from Page A to Page B with or without the option of returning to Page A again.

Tapping the lock in the center of each edge launches a popover in which you can set a precondition before the reader is allowed to traverse the edge. The precondition currently consists of whether or not the reader has picked up a key. To set these keys, the lock popover has toggle switches beside each key name in which the user may lock a path. The main screen will ultimately depict a graph representing the story the student has made with both locked and unlocked edges. Later in the story view mode of the application, the reader will see key names highlighted throughout the story text. They can tap and add these keys to their backpack, allowing them to pass through any edge locked with a key they possess.

From the main screen, the user may also double tap on any page node to launch an editing popover. The editing popover will allow them to change the name, corresponding picture, and the page description of that part of their story. As they type the description, key names are highlighted so they are aware of when they are making the keys available for pickup by a reader.

Also from the main screen, the user can play through their own story. By selecting the green play button, they are directed to The Start page of their gamebook. They can view the keys in their backpack via a popover by tapping the backpack button. They see the title, page text (including highlighted key names) and the possible next pages they can go to. If the reader attempts to visit a page whose way is locked and they don't have a corresponding key to open it, a popover notifies them that they cannot traverse to that page until they find the right key.

Figure 3.3: Interface Diagram of MacVenture

3.4 Expected Benefits

In detailing MacVenture, we begin to fill the gap that exists in merging constructivism with iPad educational technology. The design is open-ended; any subject matter can be the subject of the story. Thus, it accommodates interdisciplinary learning. The design specifies a goal of creating a game. Students using the application can feel driven to engage their friends in stories that make unexpected plot twists, pull from personal experiences, or test one another's knowledge. The design encourages users to explore several avenues of a subject they choose to write about as well as find ways to visually depict their page content. It also utilizes iPad technology to offer a service otherwise not available to students. Not only is creating a manual paper gamebook quite tedious, it cannot be shared with multiple individuals at a time. The motivation for creation really depends on the social interaction and sharing component, which is supported by studies in social constructivism and educational technology.

For a class of students, MacVenture paves the way for future research in analyzing the graph layouts different students make, and if there are patterns among grade levels and genders. For individual students, the thought process for their gamebook can be quickly and easily summarized by the layout of their graph and by analyzing graph and content complexity.

3.5 Conclusion

In this chapter, we introduced the design of our iOS application MacVenture. We provided justification for the context of a gamebook-style application in relation to constructivist learning, and outlined the purpose of our application. We detailed the requirements and objectives followed by an interface walkthrough of the final product to convey its function and use. We concluded the chapter by enumerating the benefits of MacVenture in classroom settings, and outlining the potential benefits we can see with using it for experimental studies.

Chapter 4

Examples of using MacVenture

In this chapter, we look at how the MacVenture application formulated in Chapter 3 can be applied to different scenarios involving classroom learning. Through this series, we will see the versatility of using MacVenture as a platform for learning topics in three different presentation styles: a language based storyline style in Section 4.1, a math based tutor style in Section 4.2, and a state based game style in Section 4.3.

4.1 Example One: Storyline Style

Our first example demonstrates how the application may be used for students learning the French language. Tasked with incorporating a vocabulary set given by the teacher, the student would work towards creating an interactive story using those words.

Vocabulary Set: {vais, vas, va, allons, allez}

MacVenture Graph Representation:

Given this vocabulary set, it's clear the student should understand conjugations of 'aller' and how to use them. The student may create a story about a destination trip, and in researching how to create and deliver their story, learn other terminology and subject matter.

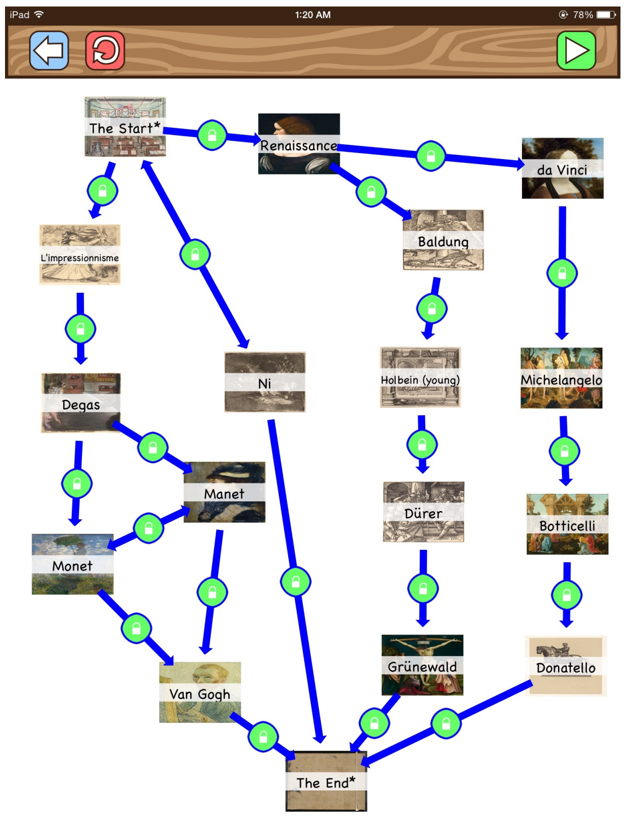


Figure 4.1: MacVenture graph depiction for Example 4.1.

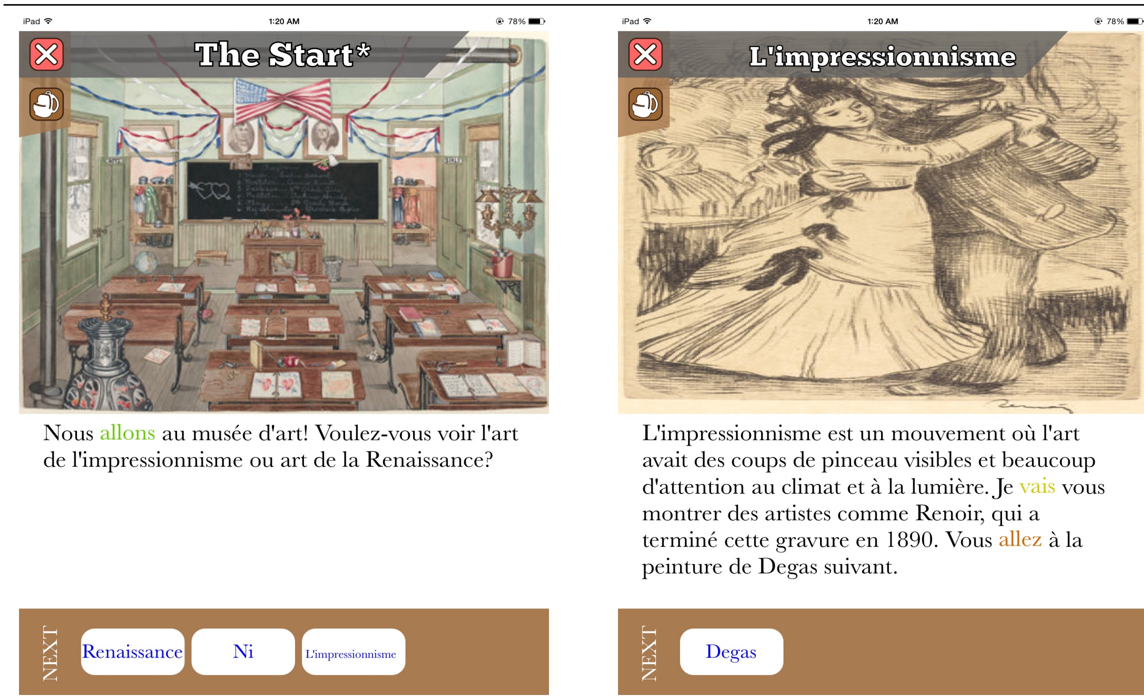
For this example, the storybook graph as seen in Figure 4.1 is representative of a tour through some art history. The beginning of the story breaks the tour into three streams. The first stream along the left side of the graph represented by the edge from *The Start** to *L'impressionisme* is to learn about Impressionism. The Renaissance branch represented by the edge from *The Start** to *Renaissance* branches again into German artists and Italian artists. The last branch from *The Start** to *Ni* (meaning "neither") represents the branch a reader may choose if they didn't want to learn about either period of art.

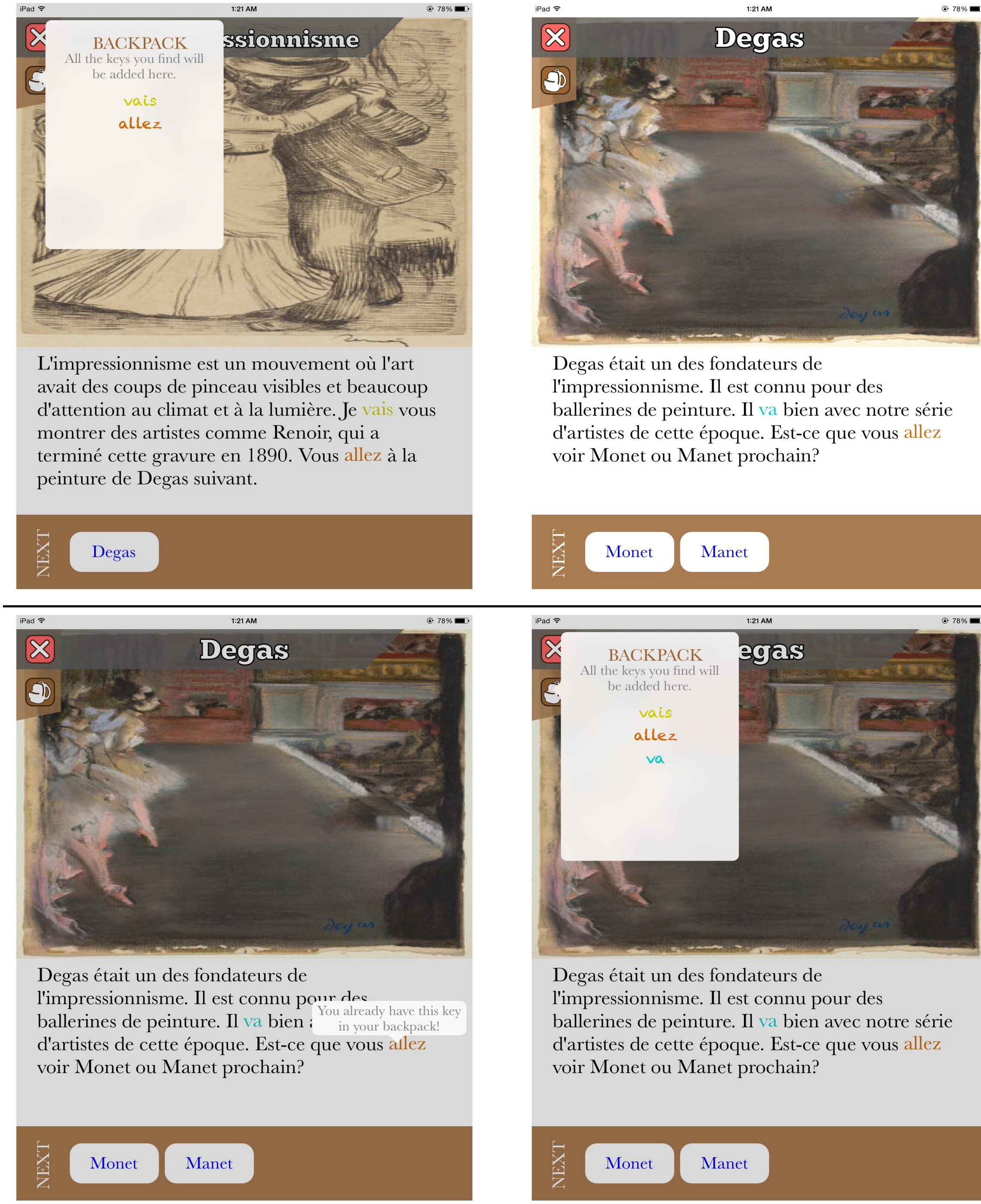
The first thing we notice is that most edges are unidirectional arrows except for bidirectional arrows in two situations: the reader may change their mind while in *Ni* and return to *The Start** to select a different path, and there is also a bidirectional arrow between *Manet* and *Monet*, since the reader may start learning first about either.

This software motivates readers to analyze the language in an attempt to understand the questions posed to them, and the options of path direction they have. For this example there are many cases in which the decision is irreversible, and the state or page they leave cannot be revisited since the majority of graph edges are unidirectional arrows. Unfortunately, we can also identify a drawback in automatically placing the start and ending nodes through this example. Written in English, they disrupt the reader's immersion in the French storyline.

Example Walkthrough

As a graphical demonstration of a possible reader's path through this gamebook's graph, let us consider the following sequence of pages: *The Start**, *L'impressionisme*, *Degas*, *Manet*, *Monet*, *Van Gogh*, *The End** as shown throught the series of images in Table 4.1. Beginning with *The Start**, the reader reads the description detailing that they are going to an art museum, and the text asks whether they would like to go see Renaissance art or Impressionism. Note how the subsequent pages are offered below as buttons, automatically generated from the gamebook's graph drawing. Also note how "allons" is highlighted in green, which indicates that the text is actually interactive. If the reader taps the text, they "pick up the Key" so to speak, and it is added to their "backpack". From *L'impressionisme* they may start picking up keys such as "vais" and "allez". These are added to the backpack, which we can see does not contain "allons" since it was not tapped or "picked up". The reader then works through subsequent pages, attempting to pick up a new key and an already obtained key in *Degas*, opting to visit *Manet* before *Monet*, and scrolling through the longer description available for *Van Gogh* before reaching *The End**.




iPad
1:21 AM
78%
ssionnisme
BACKPACK
All the keys you find will be added here.
vais
allez
L'impressionnisme est un mouvement où l'art avait des coups de pinceau visibles et beaucoup d'attention au climat et à la lumière. Je vais vous montrer des artistes comme Renoir, qui a terminé cette gravure en 1890. Vous allez à la peinture de Degas suivant.
NEXT
Degas
Degas
Degas était un des fondateurs de l'impressionnisme. Il est connu pour des ballerines de peinture. Il va bien avec notre série d'artistes de cette époque. Est-ce que vous allez voir Monet ou Manet prochain?
NEXT
Monet
Manet
Degas
Degas était un des fondateurs de l'impressionnisme. Il est connu pour des ballerines de peinture. Il va bien avec notre série d'artistes de cette époque. Est-ce que vous allez voir Monet ou Manet prochain?
You already have this key in your backpack!
NEXT
Monet
Manet
egas
BACKPACK
All the keys you find will be added here.
vais
allez
va
Degas était un des fondateurs de l'impressionnisme. Il est connu pour des ballerines de peinture. Il va bien avec notre série d'artistes de cette époque. Est-ce que vous allez voir Monet ou Manet prochain?
NEXT
Monet
Manet

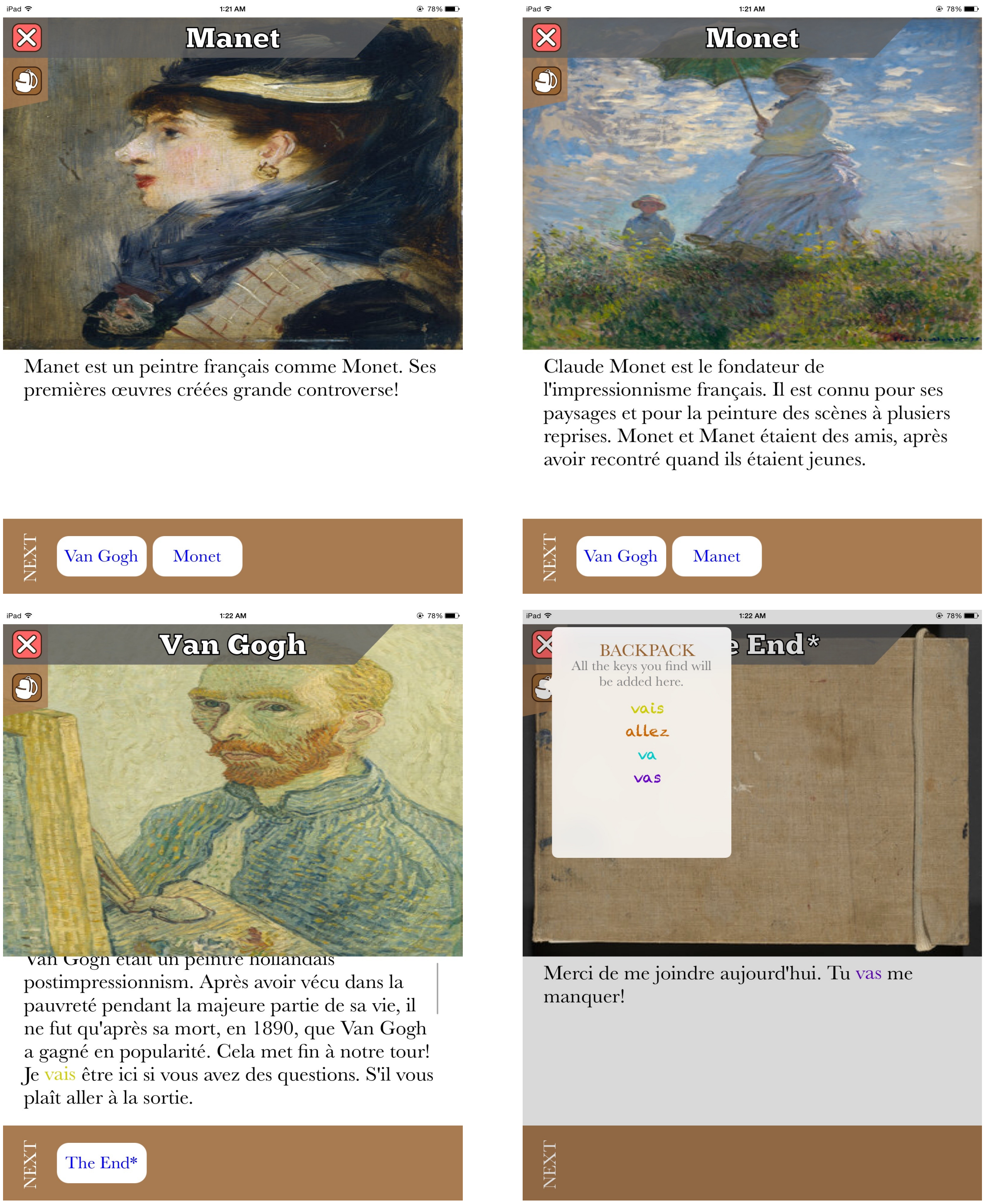


Table 4.1: User Interface Walkthrough of Example 1

4.2 Example Two: Interactive Textbook Style

Similar to how *TutorText* is designed, MacVenture can be used by students to create gamebooks reflective of interactive textbooks. When students work on independent study units or independent projects, the culmination project usually includes a classroom presentation to their peers to share their knowledge. By exploring a topic, gathering information, creating the surrounding context and defining possible decision points, the student actively constructs their understanding of the subject and possible pitfalls in understanding.

Vocabulary Set: none assigned

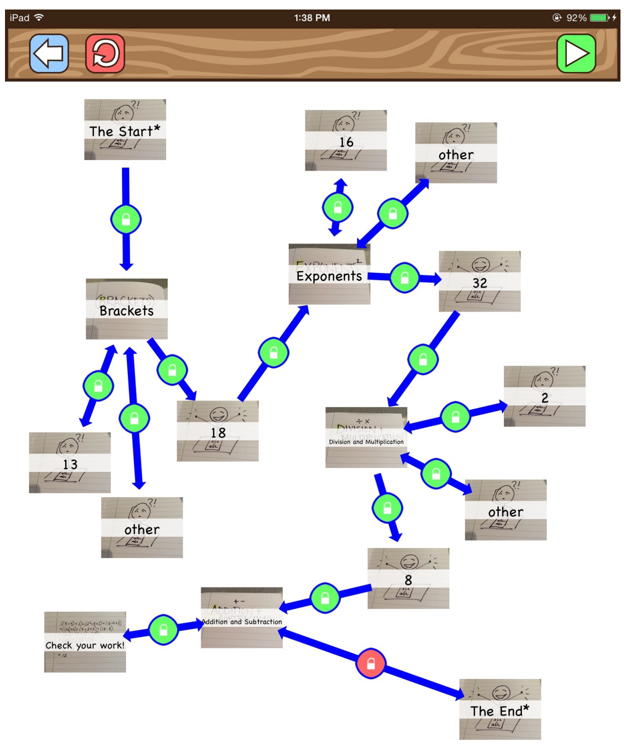


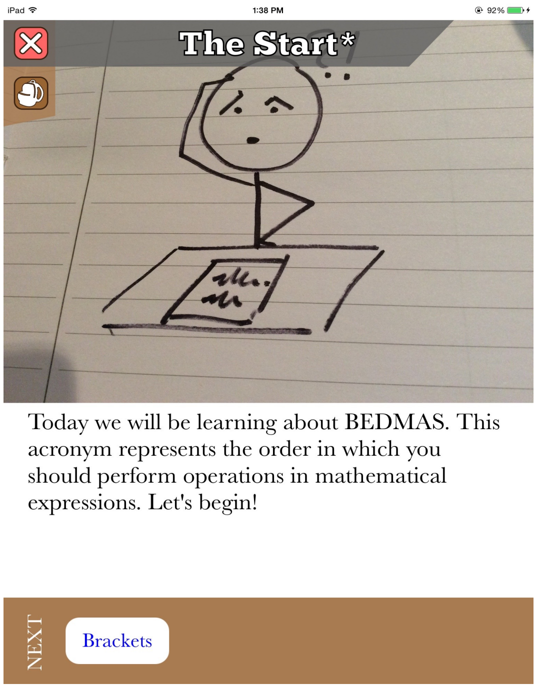
Figure 4.2: MacVenture graph depiction for Example 4.2.

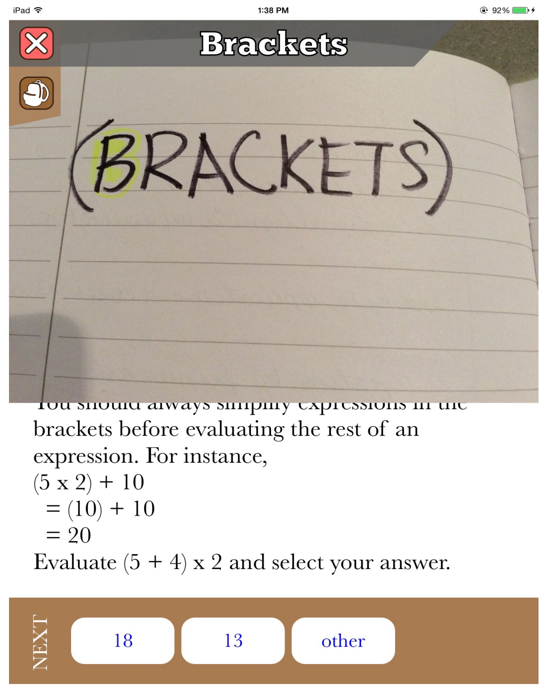
This particular example reflects what a student may create as a mathematics drill exercise for their peers. The topic in this situation is the order of operations for evaluating expressions. The student can create questions, and when creating options for the solution, actively try to anticipate and understand common mistakes that other students may make. This graph in particular linearly takes the reader through the order of operations with several branching options of solutions, only one of which is correct and will allow the reader to continue. A lock exists within this graph at the end. After posing a bigger question, the next Places indicated are “The End*” and “Check your work!”. Students are actually forced to check the solution before finishing, as noted through the walkthrough. Another point of interest is the images used throughout this creation. Students can sketch representative doodles or solution pieces as the pictorial parts of their story, take photos of their work using the iPad, and upload those images to the game’s view from their photo gallery.

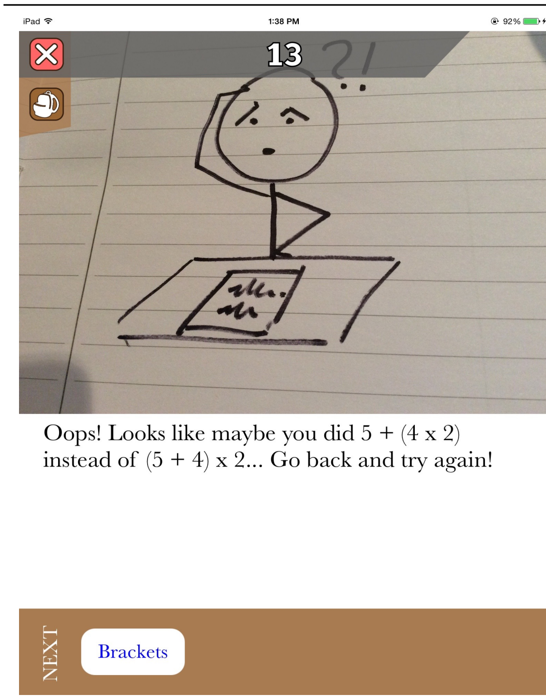
Example Walkthrough

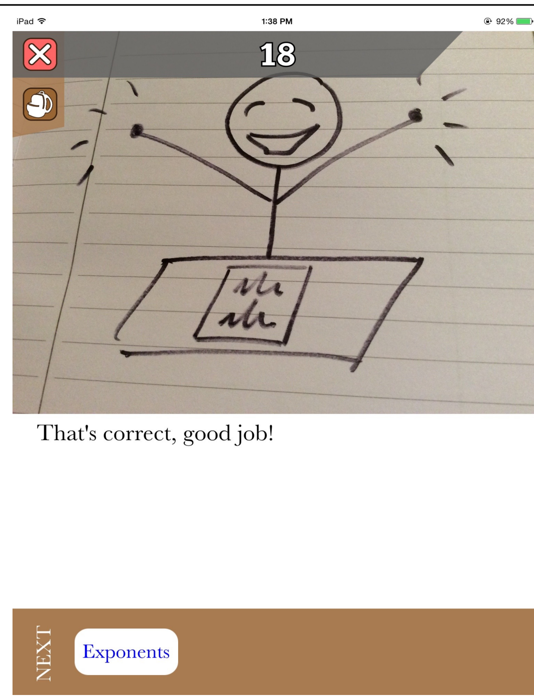
In this example, we pass through the following sequence of pages: *The Start**, *Brackets*, *13*, *Brackets*, *18*, *Exponents*, *16*, *Exponents*, *32*, *Division and Multiplication*, *8*, *Addition and Subtraction*, *Check your work!*, *The End**, as shown throught the series of images in Table 4.1. We can see that readers are looped back to the questions presented in *Brackets* and *Exponents* when they do not answer correctly the first time. The story creators, having offered alternative solutions, have the opportunity to explain why the common errors they included as solutions might be wrong, offering feedback to the reader to steer them in the right direction. At the end of the walkthrough, we can see the reader immediately tries to skip to the end of the storyline without checking their work. This is a great opportunity for a lock to be introduced, as it forces the user to one page to pick up a Key before finishing. Of course, we could have directed the graph to simply pass the reader through the checking phase instead of posing the option of going to The End*, but this illustrates the interface feedback on the utilization of locks.

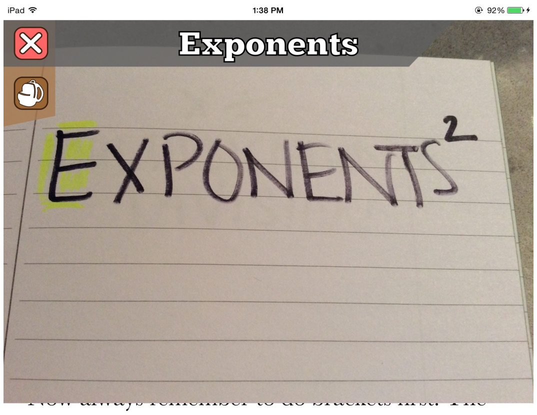
Locks could also be utilized as rewards in this case. They game could also be structured with answers that do not force the reader to complete one section before another, but have an open web of opportunities to traverse through. Then the Key names could be included in the descriptions for the correct answers, and only with the Key names could the reader enter The End*. Undoubtedly, there are a lot of variations, but the point is that tutor-style teaching can be supported through the anticipation of incorrect answers, and the communication and justification for why they are wrong.


iPad
1:38 PM
92%
The Start*
Today we will be learning about BEDMAS. This acronym represents the order in which you should perform operations in mathematical expressions. Let's begin!
NEXT
Brackets


iPad
1:38 PM
92%
Brackets
(BRACKETS)
You should always simplify expressions in the brackets before evaluating the rest of an expression. For instance,
(5 x 2) + 10
= (10) + 10
= 20
Evaluate (5 + 4) x 2 and select your answer.
NEXT
18
13
other

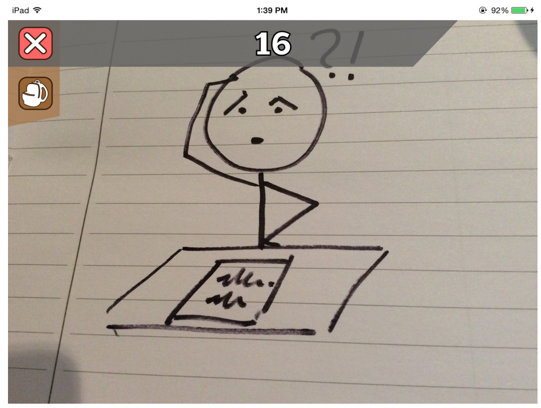

iPad
1:38 PM
92%
13
Oops! Looks like maybe you did 5 + (4 x 2) instead of (5 + 4) x 2... Go back and try again!
NEXT
Brackets


iPad
1:38 PM
92%
18
That's correct, good job!
NEXT
Exponents



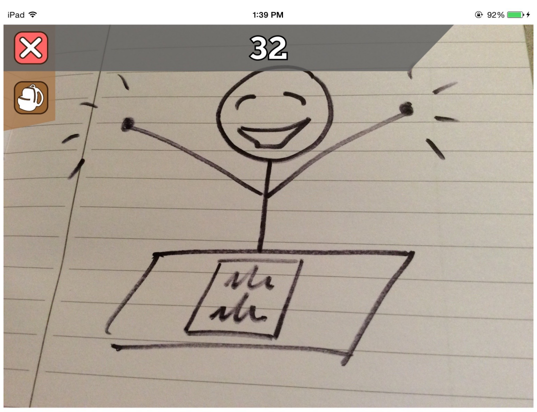
second part of the expression you should try and evaluate is any exponents. For instance:
3^2 +1
 = 9 + 1
 = 10
Now you try! Evaluate (3 + 1)^2 x 2.

NEXT | other | 16 | 32



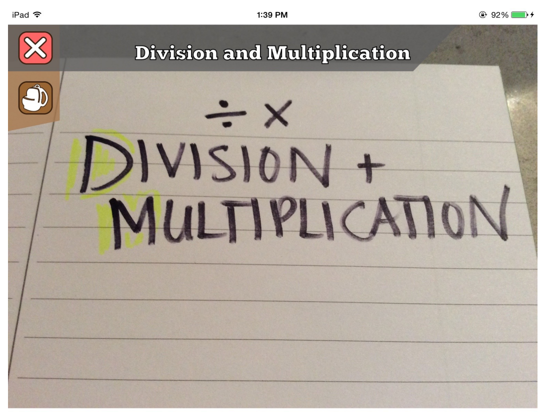
Oops! Looks like maybe you did (3+1)x2x2!
Remember that 4^2 = 4x4 not 4x2.

NEXT | Exponents



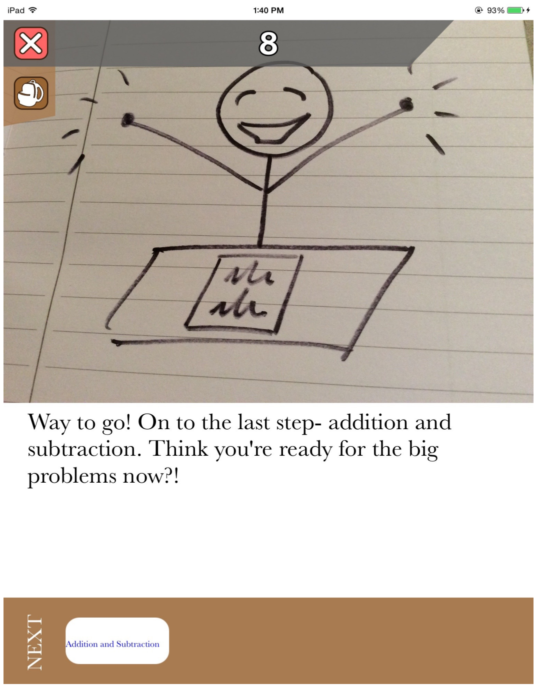
Correct! Way to go!

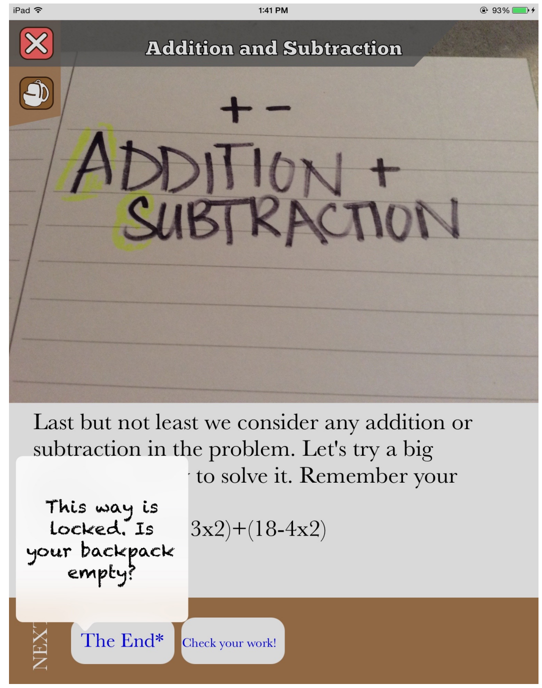
NEXT | Division and Multiplication

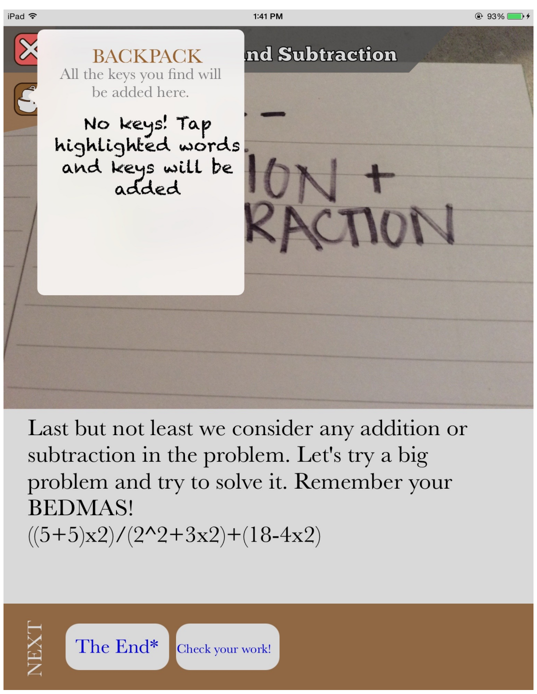


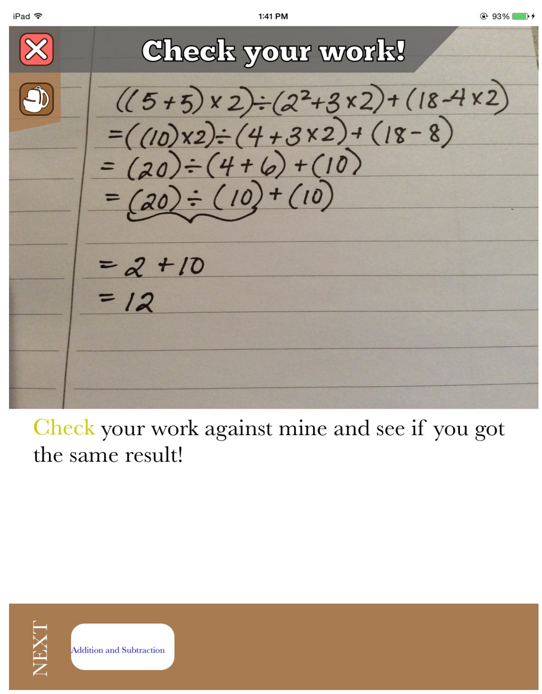
After brackets and exponents, we consider division and multiplication.
Evaluate 4 x (3+1)^2 / 8

NEXT | 8 | other | 2


8
Way to go! On to the last step- addition and subtraction. Think you're ready for the big problems now?!
NEXT
Addition and Subtraction


Addition and Subtraction
+ −
ADDITION +
SUBTRACTION
Last but not least we consider any addition or subtraction in the problem. Let's try a big
to solve it. Remember your
3x2)+(18-4x2)
This way is locked. Is your backpack empty?
The End*
Check your work!


nd Subtraction
BACKPACK
All the keys you find will be added here.
No keys! Tap highlighted words and keys will be added
Last but not least we consider any addition or subtraction in the problem. Let's try a big problem and try to solve it. Remember your BEDMAS!
((5+5)x2)/(2^2+3x2)+(18-4x2)
NEXT
The End*
Check your work!


Check your work!
((5+5)x2)÷(2²+3x2)+(18-4x2)
=((10)x2)÷(4+3x2)+(18-8)
=(20)÷(4+6)+(10)
=(20)÷(10)+(10)
=2+10
=12
Check your work against mine and see if you got the same result!
NEXT
Addition and Subtraction

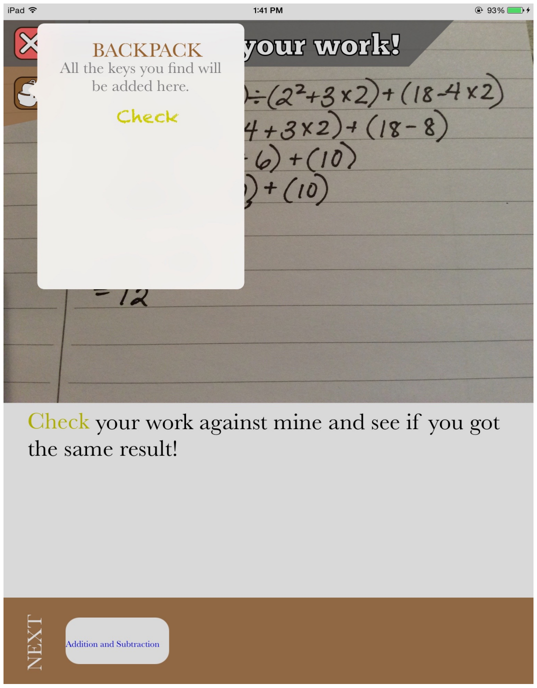
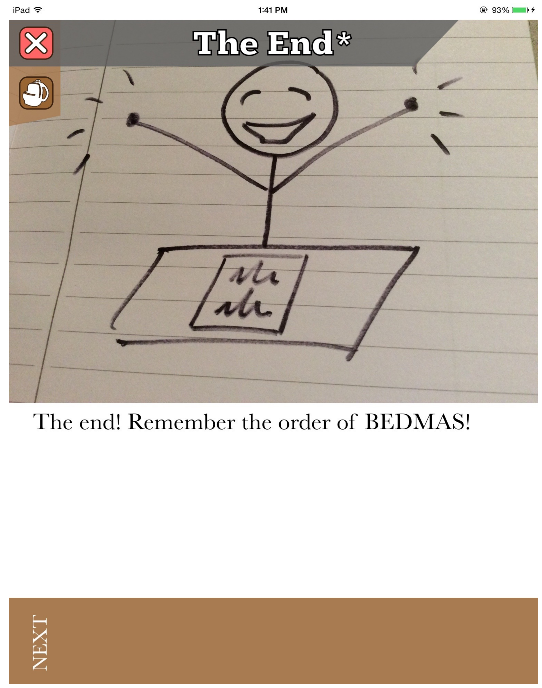
	

Table 4.2: User Interface Walkthrough of Example 2

4.3 Example Three: State-Based Game Style

In this example, we show a simple illustration of how the graph can also be used as a small state-based game. The premise for this design is similar to that of a "needle-in-the-haystack" where the reader searches for The End* amongst a multitude of pages named The Start*. Actually inspired by a student who created and shared a similar gamebook design (with many more Places) in an outreach workshop, this exploits how the graph pages are only identified by their names. By multiplying the number of nodes that are not The End*, the gamebook's author populates the story with "searching pages" keeping the reader in a searching state, unaware if they are continually traversing through some of the graph's cycles. Upon finding a searching state neighboring The End*, they can finally finish the game.

Vocabulary Set: none assigned

MacVenture Graph Representation

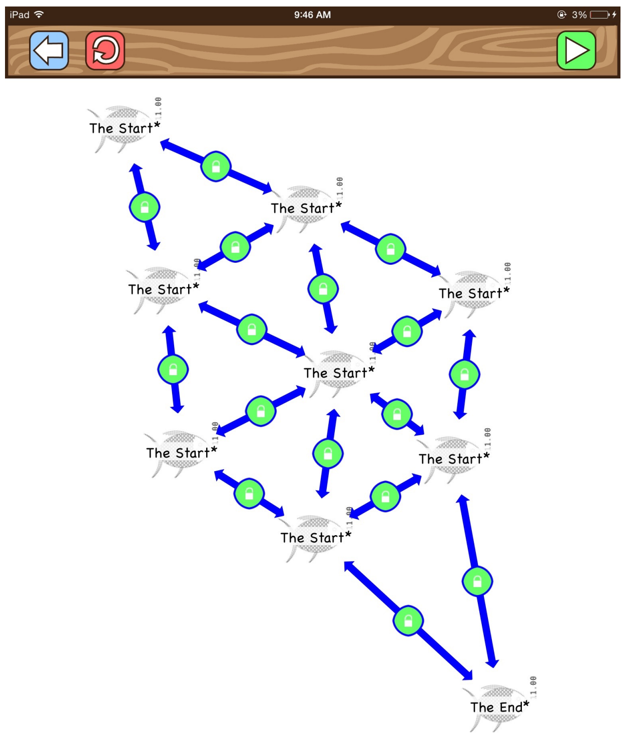


Figure 4.3: MacVenture graph depiction for Example 4.3.

In this example, the graph offers bidirectional movement through all the pages, with several cycles existing in the graph. The searching pages are all nearly identical, except various nodes in the graph have a different amount of neighbors (called a nodal degree). Of course, a reader could pick up on this differentiation, or the creator could make a graph where all searching nodes have the same degree.

Since the game is simple, the walkthrough in Table 4.3 just illustrates one path through which the reader might navigate. One can see by the third image that the reader is beginning to get into the nodes with the highest degree, but lucklily selects a node from there which directs them to The End*.

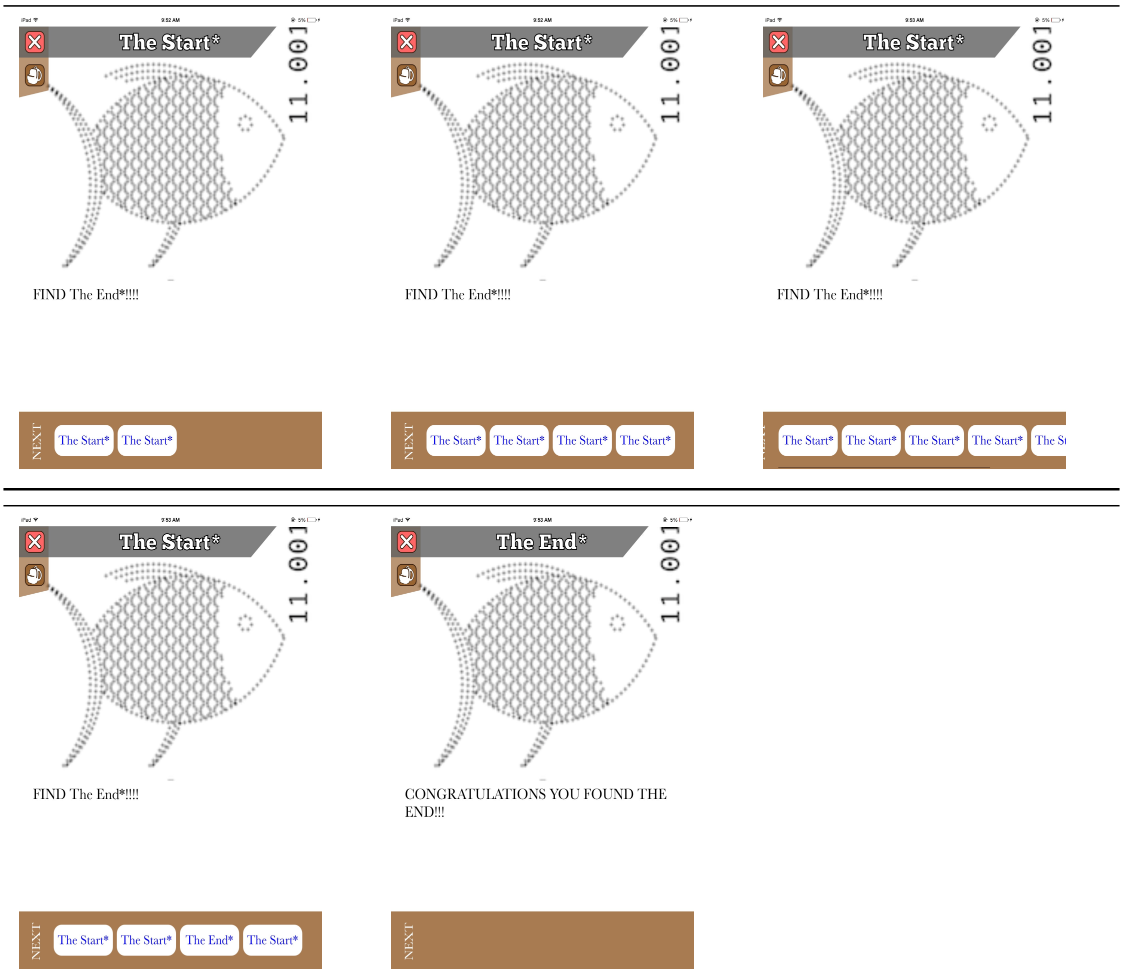


Table 4.3: User Interface Walkthrough of Example 3

4.4 Conclusion

In this Chapter, we considered the application of MacVenture in three different ways: in a storyline-based language application, in a math-based tutoring application, and in an entertainment-based game application. These examples demonstrate the diversity of the platform. We presented three examples of use, beginning with Example 4.1 which detailed an exploratory style of learning, in which one student can research and prepare an environment that another student can traverse through and learn from while making decisions on what they want to learn given the available options. In Example 4.2 we provided a basic example of tutor style use. In this case, one student prepares questions, anticipates wrong answers in addition to correct answers, and attempts to justify to the reader how they may have strayed from what is correct. This supports the idea of fully understanding concepts through teaching others. Lastly, in Example 4.3 we considered a carefree representation of a searching game, in which the reader may continually search through a maze of pages to find the page they are looking for.

Chapter 5

Discussion

In this chapter, we discuss the various aspects and considerations concerning the use of MacVenture. In Section 5.1, we discuss the general application of using tools like MacVenture in the classroom, providing a more holistic context for which some of our examples in Section 4 could be applied. In Section 5.2 we address the strengths and weaknesses concerning the application and its use.

5.1 Discussion

MacVenture has been iteratively developed while in use by McMaster's Computing and Software Outreach program. Having the outreach program has been an indispensable resource for our work, and using outreach programs for introducing new techniques in teaching has multiple benefits. Many of these benefits actually immediately address some of the "environmental" obstacles noted in educational technology use. One issue concerns the accessibility of technological resources, which for our purposes would include a school's access to approximately thirty iPads for a classroom of students to use. The outreach team owns its own set of iPad minis it uses for any workshops teachers sign up for. This makes iPad-based teaching accessible to any school in the area who books free workshops with the team. A second issue commonly noted throughout literature is that teachers feel that the technology based education lacks direction and they themselves are not confident in leading technology based activities. In using outreach workshops, the volunteers are confident in their presentations, and understand the point and focus of the activities. Many times the teachers will watch our volunteers troubleshoot issues or address problems, and we will later see the teachers fixing similar issues for other students. The last environmental issue we can address through using an outreach team is selecting the appropriate applications for activities. In this case, our team also works on developing applications, so we may be biased towards introducing schools to applications the team creates over other available applications. However, this provides the opportunity for school members to request the development of specific functionality in our applications.

MacVenture acts as an open-ended platform for gamebook creation. As seen by the examples illustrated in Chapter 4, the content can be chosen to incorporate a diverse range of subjects, and in a variety of different ways. The application is not meant as a primary teaching mechanism, but as a support tool for classrooms to encourage further research in a field and have students discuss their findings amongst one another. It encourages exploratory learning, discussion of content application, problem identification, problem solving, logical reasoning, cooperation, and communication. Note that the application could also be projected on an overhead screen, and act as the presentation itself whereby the student may read their story aloud, and their peers vote upon responses at decision points.

5.2 Assessment of the Contributions

In this section, we will consider both the strengths and weaknesses of our work presented on MacVenture and how these contribute to the fields of research in learning theories and educational technology.

5.2.1 Strengths of the Contributions

The fields of learning theory research and educational technology research both hold a considerable amount of theory-based content. This of course is necessary to the fields, but they tend to both criticize the incomplete implementation of their learning models in schools. Many empirical studies for educational technology use preexisting software built by other institutions or agencies to aid them in their research goals. Many studies on the implementation of learning theories evaluate preexisting educational software against theoretical models researchers have created. However, academic discussion does not magically appear in the classrom, and the issue lies with the expectation that educational software will change without guidance. In this sense, if we have research mapping learning theories to implementation approaches, and one of those approaches maps well to mobile software, there needs to be communication between those who understand learning, and those who understand software development. Without this, the products the developers create will never meet the requirements set out by the learning theorists, and so the software's effectiveness will always be called into question when creating empirical studies to compare learning styles. The biggest contribution is the bridge between these two fields that MacVenture provides, and the opportunity for discussion and collaboration between experts in either field.

Another strength of MacVenture is the unique opportunity the application affords students in learning. Not only is the application's functionality irreplacable by traditional teaching, it allows the students the ability to identify themselves through their work. They can compare their work with other students not by how they perform in grades as behaviorist teaching would have, but in the experiences they communicate through their storylines, or the challenges they set for their peers to overcome. In this case, the collaboration is not even (necessarily) noisy or disruptive, but can be offered as quiet sharing opportunities. Their peers, who would traditionally be simply passively reading a story, now get to interact and make decisions in a context wholly created by their fellow student.

5.2.2 Weaknesses of the Contributions

There are several weaknesses in this work's contributions that we aim to address in future revisions of MacVenture and the ongoing development of the system as a whole. One of the main weaknesses is the lack of detail on the teacher's application, which comprises the second half of our vision of the system. It will make a much larger impression on the field to have the secondary application finished, and some formal preliminary results from students and teachers on the reception of the system, and the incorporation of the activity into curriculum work. Another major weakness is the lack of learning theorists on our developmental team. We have surveyed the research available in the field and used it to guide the design of our application, but it would be very beneficial to have a psychologist's perspective on the direction and future considerations we should take with MacVenture and the forthcoming teacher's application. This is something we aim to address in future work.

5.3 Conclusion

As discussed in this chapter, MacVenture offers a unique learning opportunity for students. In detailing its design, it bridges a gap between two sets of research in academia. Using MacVenture alone, it offers insight into the student's interests, their personal experiences, and how they understand a given context as a whole. By allowing the student to construct their own environment of decision-making and results, they can customize their work as a hybrid of learned knowledge and past experiences. However, MacVenture does need to have some additional feedback and support from researchers and psychologists in learning theories as a part of the next step on integrating it into the larger system with the teacher's application.

Chapter 6

Conclusion and Future Work

In this chapter, we will summarize and conclude our work. In Section 6.1, we will outline the next steps for MacVenture, and the ways in which our research group anticipates using it. This includes our direction on the additional teacher's application as introduced throughout this work, and the general benefits we hope to achieve from our entire system when the teacher's application is finished. Finally, we summarize and conclude our work with Closing Remarks in Section 6.2.

6.1 Future Work

Completing MacVenture is the first step in developing a mobile learning application system geared to assist and motivate teachers and students alike. Throughout this section, we will detail the next steps we are working towards achieving. Beginning with a look at MacVenture, we discuss some of the work we plan to do to improve communication and collaboration between students, as well as different ways the application can better interact with the student while they use it. Next, we will discuss the general objectives for the next critical application for our overall system: the teacher's application. Finally, we will discuss how we anticipate these components to work together, and what kind of information a system like this can provide to the teacher.

6.1.1 Additions and Improvements to MacVenture

There are still a few aspects of MacVenture that need improvement. Firstly, the tutorial section should have an interactive tutorial so students can practise the application's mechanics before beginning their own gamebook creation. Next, there are some user interface design features that need improvement, including the ending page, which could include some celebratory animations for the gamebook reader to feel accomplished. We are also interested in allowing students to zoom in and out of the graph creation page, allowing for larger graphs to be designed, and more room to customize the appearance of the graph itself (i.e. allowing an opportunity to start clustering nodes). An interesting addition would be to the lock mechanisms on the edges which we would like to use as an opportunity to introduce students to discrete mathematics and logic. Incorporating a slightly more advanced interface would allow boolean operators between key names which would increase the potential complexities of games. A major functional component we would like to introduce is concurrency in building gamebooks between multiple devices. By allowing students to work together on a single gamebook's creation we introduce potential issues in resource management. One approach to undertake these issues is to offer multiple students read and write privileges to the main graph creation page, and then offer only write privileges to pages they create within the graph. Of course, they would be allowed read privileges to the pages their partner makes. Lastly, we are interested in porting the application over to Android to allow schools without iOS tablets the same opportunities.

6.1.2 General Objectives for the Teacher's Application

The teacher's application will offer much more versatility and usability to the system as a whole. The first objective for the teacher's application is to be able to send customized Keys to the students for use. This idea could be extended in multiple ways, perhaps later also allowing the teacher to customize and send the Place names they want the students to use in their creations. In this way, the teacher may provide a basis upon which the students can generate their stories, while keeping the activity time spent on the exercise still related to the curriculum content they need to cover.

This secondary application will also be responsibile for data collection and analysis. Ideally, the application should be able to compile the text descriptions of the students and extract information the teacher may be interested in. Some interests may include:

(i) A list of the most commonly used words throughout each student's creation

(ii) The number of Places in each student's gamebook

(iii) The average word count of each student's Place descriptions

(iv) The average word length of each student's Place descriptions

(v) Comparisons of students' story subjects by age and/or gender

(vi) Comparisons of students' graph drawings

(vii) Comparisons of students' graph features such as number of nodes, edges, cycles, diameter etc.

While convenient to also create this as an iOS iPad Application, we are also considering hosting the application on other platforms with larger screens considering the large amount of data and data processing this application will be expected to handle. In addition, we will have to consider the ease with which the teacher will be able to view the results from the data analyses and comparisons. It would be ideal for the teacher to be able to customize the types of data analyses they are interested in.

6.1.3 Future Goals in Data Analysis

As detailed in Subsection 6.1.2, the teacher's application will be responsible for a host of opportunities in data analytics. Not only will this information be of use to the teachers themselves, but it may also be interesting for university researchers in several fields. First, this system can contribute to the field of learning theories, which was our original motivation. Studies can be designed to analyze the improvements in student understanding as compared between simply playing through the gamebook, individually creating and playing through another's gamebook, and concurrently creating a gamebook with another student before playing through another's creation. This will help fill a void in empirical research in the field of learning theories, as well as create an opportunity to discuss strengths and weaknesses in how applications are currently approaching student learning.

The system as a whole also contributes to the field of graph drawing. The application allows students to create graphical representations of information. How they decide to cluster and display this information is up to them, and as the graphs become larger this could act as a means to better understand the process by which they choose to improve the appearance of their graphs. This provides us an insight into how students view, understand, and manipulate graph configurations. This system could also be used as the tool by which researchers in graph drawing algorithms conduct, compile, and analyze their research.

6.2 Closing Remarks

Throughout this work, we have described the design and implementation of MacVenture, an iPad application geared toward elementary school students that enables users to create their own gamebook-style adventure story to share with peers. Motivated by our background in computer science outreach and our interest in student learning, we reviewed literature pertaining to the social constructivist learning theory and other research specifically addressing the design parallels the theory holds with the affordances of mobile technology. We then considered how some educational applications have been designed with respect to learning theories, both by reviewing other literature that make these comparisons and also by reviewing some applications ourselves. Ultimately, this background research uncovered two facts: there are very few social constructivist educational applications available, and there are very few software designs detailed for academic use to bridge the fields of learning theories and application development. As a result, there are scarce amounts of empirical research in the use of social constructivist mobile applications. To begin to address this void, we have developed MacVenture, which will eventually be used in collaboration with another teaching application to offer a platform for engaged learning for the students and automated analytics for the teacher. We provided the software design of MacVenture, in addition to some examples of its use. We discussed the strengths and shortcomings of the application, discussed the intended future work on this project, and the opportunities for research this work could provide.

In conclusion, MacVenture acts as the first step to providing sound research in the area of social constructivist mobile learning. It has been developed considering the shortcomings of implementations of the learning theory, issues with educational technology and further problems concerning iPad applications in classroom environments. Through an iterative process observing students from outreach activities interact with it, and also from the feedback they explicitly offered, we have built an application that acts as a flexible platform for innovative learning. It challenges students to seek out knowledge independently, incorporate their own experiences and preferences, and teach their peers in a creative manner. The application urges students to consider how not only they would react to questions, but how others will think and learn, how others will make decisions, and how those decisions should affect outcomes and results. Through not only playing but creating gamebooks, students are propelled to consider all potential outcomes. It is a tool with which students not only to communicate why something's right, but why it's wrong; it is a tool for which students not only learn beside one another, but learn with one another.

> Learning is more than the acquisition of the ability to think; it is the acquisition of many specialized abilities for thinking about a variety of

things. *-Lev Vygotsky*

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