Configurable Persuasive Games

THESIS

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Abstract

Serious games — games that are designed and developed for the primary purpose of education rather than pure entertainment, have been used widely as an active learning platform. However, these games can do more than just teach. Serious games can be used to change attitudes and beliefs of players. Such serious games, called 'persuasive games', can engender significant long-term changes in players. This thesis presents a web based, multiplayer, persuasive game called GeoGame, that teaches the complex, real-world semantics of the Green Revolution to Geography students. GeoGame is developed with a purpose of changing the attitudes of students towards farming in developing countries.

In this thesis, we review the architecture of the game and present results of the user testing conducted to evaluate the effectiveness of the game. The architecture consists of three components — namely a game component, an assessment system and persuasion system. The game component consists of a lightweight web platform that merges multiplayer online gaming technology with online geographic information systems (GIS) technology, to allow players to experiment and interact with the geospatial data. The assessment system is a flexible and easily configurable system, which is used to make rigorous assessment of the benefits of the developed platform. The persuasion system implements features to increase the motivation of students and analyzes how the engagement of students with and their attitudes toward a subject may change as a result of using the GeoGame platform.
Dedication

This thesis is dedicated to my family and friends.
Acknowledgments

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Table of Contents

Abstract .............................................................................................................................................. ii
Dedication ........................................................................................................................................ iii
Acknowledgments ........................................................................................................................ iv
Vita ...................................................................................................................................................... v
List of Tables ...................................................................................................................................... x
List of Figures ..................................................................................................................................... xi

Chapter 1  Introduction .................................................................................................................. 1
  1.1.  Background and motivation ................................................................................................ 1
  1.2.  Contribution .......................................................................................................................... 3
  1.3.  Organization of this document ............................................................................................ 4

Chapter 2  Literature Review ......................................................................................................... 6
  2.1.  Problems with traditional teaching methods ........................................................................ 6
  2.2.  Why use games? ..................................................................................................................... 7
  2.3.  Understanding serious games ............................................................................................... 8
    2.3.1.  Categories of serious games .......................................................................................... 8
    2.3.2.  Introduction to simulation games ................................................................................... 8
3.4.3. Dynamic view of subsystem interactions ........................................ 28

3.5. Turn change module ........................................................................... 31

3.5.1. Server polling .................................................................................. 31

3.5.2. Server side push .............................................................................. 32

Chapter 4 Assessment System ................................................................... 35

4.1. Assessment in GeoGame ................................................................. 35

4.2. Assessment system architecture ......................................................... 38

4.3. Interceptor ......................................................................................... 43

4.4. Rule engine ......................................................................................... 44

4.5. Admin module ..................................................................................... 44

Chapter 5 Persuasion Aspects of GeoGame .............................................. 47

5.1. Persuasive games .............................................................................. 47

5.2. Persuasion theory .............................................................................. 48

5.2.1. Intrinsic vs. Extrinsic motivation .................................................... 48

5.2.2. Self Determination Theory ............................................................. 49

5.2.3. Elaboration Likelihood Model (ELM) of persuasion ...................... 50

5.3. Persuasion in GeoGame ................................................................. 51

5.3.1. Persuasion features that increase player motivation ..................... 52

5.3.2. Features implemented in GeoGame .............................................. 53
List of Tables

Table 1. Literature review on effects of educational games. .............................................. 9
Table 2. Population description from the 2012 Fall semester ........................................... 58
Table 3. Population description from the 2013 Spring semester. ...................................... 62
List of Figures

Figure 1. Overview of formative and summative assessments.......................... 14
Figure 2. Information Trails: In-process assessments........................................ 16
Figure 3. Game description............................................................................. 19
Figure 4. Architectural decisions................................................................. 22
Figure 5. Dynamic view of server interactions.............................................. 25
Figure 6. Subsystems and contracts............................................................. 27
Figure 7. Dynamic view of subsystem interactions........................................ 29
Figure 8. Server polling.......................................................... .......................... 32
Figure 9. Server side push............................................................................ 33
Figure 10. Components of Information Trail.................................................. 37
Figure 11. Architectural decisions for assessment system............................ 39
Figure 12. Dynamic view of assessment system interactions.......................... 42
Figure 13. Admin module DB schema.......................................................... 45
Figure 14. Admin screen with rule editor...................................................... 46
Figure 15. Elaboration Likelihood Model....................................................... 51
Figure 16. Avatar grid.............................................................................. 54
Figure 17. 2012 Fall semester survey results................................................ 58
Figure 18. Attitude shift towards farming (2012 Fall semester)....................... 60
Figure 19. 2013 Spring semester survey results............................................ 63
Figure 20. Attitude shift towards farming (2013 Spring semester). .................................. 64

Figure 21. Impact of persuasion features. ............................................................................. 65
Chapter 1  Introduction

1.1. Background and motivation

Computer games are a growing part of our social and cultural environment. The predicted growth of the gaming industry in the coming years -from $67 billion in 2012 to $82 billion in 2017 [1] indicates the widespread popularity of computer games. Though a large number of games are mainly developed for entertainment, there is a growing use of games to do more than just entertain.

Games which are specifically designed and developed for the primary purpose of education, rather than pure entertainment, are called "serious games" [2]. In last few years, games have been widely used for education because they are shown to develop skills like problem solving, communication, and collaboration [3]. Simulation games, in particular, provide an active learning environment where students learn by direct application rather than memorization of rote facts. By applying the educational potential of serious simulation games, it is possible to provide students with meaningful opportunities to develop a deeper understanding of the subject.

One such application of serious simulation games is in the field of Geography. Geography is the science that studies the lands, the features, the inhabitants, and the phenomena of the Earth [4]. Understanding the economical, political, scientific, and military impacts of geography has become crucial [5]. Geospatial cyber infrastructures
have become increasingly central to support emergency services, transportation, urban planning, environmental hazard management, military operations, and relief operations [6]. Geospatial is the term widely used to describe the combination of spatial software and GIS [7]. Geospatial cyber infrastructures are important to understand some of the world's most pressing problems such as climate change, environmental sustainability, global security, and biodiversity [8]. Despite this, interest in teaching and learning about geography is declining. As a result geographic literacy is alarmingly low in the U.S. [9]. According to a survey by Castleford (1998) [10], lecture is still the principal teaching mode by Geography instructors. There are many studies that indicate the need for a shift to new teaching methods [5].

Although using rich learning environments (e.g. presentations, graphics and multimedia packages) can be useful, these will not help if the same old content is transferred through these technologies. None of the media mentioned above provide the interactivity that serious games provide. Serious games provide an active learning environment, which has been shown to vastly improve retention and understanding of the material being taught [11].

Therefore, the potential to develop and explore innovative use of geospatial and gaming technology for teaching and learning of complex geographical concepts would have significant benefits. Both geospatial and gaming technology have the potential to create platforms for cyberlearning that allow for interaction with a plethora of scientific data [12].
Such an integrated platform should also allow instructors to define and evaluate the learning goals. Teachers cannot hand out a game to a group of students and assume that they have learned the material. One main challenge in using games for educational purpose is to make valid inferences about what student learned through games [13]. Therefore, the game should contain a component which measures learning outcomes of the game without disrupting the flow of the game.

Seamless flow within serious games is very important to keep students intrinsically motivated and emotionally engaged. Contemporary research has shown that games which are intrinsically motivating can be used to change fundamental attitudes and beliefs [14]. Such games are called 'persuasive games'. The player gets immersed into the game so much that he/she loses track of time. This immersive environment is the primary reason why games are effective in persuasion [15]. Therefore persuasive games should include features which increase student's emotional involvement in the game.

1.2. Contribution

The key goals of this research is to build a system consisting of three main components:

1. Game component: Develop a light-weight web platform that merges multiplayer-online-gaming technology with online GIS technology, allowing users to experiment and interact with geospatial data. Explore and evaluate .NET architectures for rapid and flexible game development.

2. Assessment system: Make rigorous assessment of the benefits of the developed platform as an active learning environment.
3. Persuasive aspects: Understand how students’ engagement with and their attitudes toward a subject may change as a result of using the developed platform.

These goals were accomplished through a two-step process.

First, a web-based, multiplayer, simulation game was developed at The Ohio State University for teaching complex, real-world semantics of the Green Revolution to geography students. The ASP .NET MVC3 framework was used for rapid and flexible game development. An ArcGIS server by Environmental Systems Research Institute (ESRI) provided geospatial processing capabilities. Using well-defined principles of persuasion [16], an avatar feature was developed and evaluated to increase students engagement in the learning environment. To evaluate the game based learning, an innovatively configurable assessment system was built.

Second, the developed serious game was play tested with 186 students previously unfamiliar with the game. Students played through seven rounds of the game. Between every round, the assessment system asked in-game questions which students had to answer to proceed. At the end of the game students were provided with a voluntary survey. Student responses to in-game questions and the voluntary survey were analyzed to assess their attitude change towards the subject.

1.3. Organization of this document

Chapter 2 gives a brief overview of serious games and lists some of their essential characteristics. This chapter also discusses few challenges faced in the game-based assessment and presents new techniques used to overcome these challenges. Chapter 3 explains the game concept and describes the architecture of GeoGame. Chapter 4
presents a detailed description of the assessment system implemented within the game. Chapter 5 focuses mainly on the persuasive component of the game. Chapter 6 presents the evaluation of the game based on the user testing analysis. Conclusions and proposed future work comprise Chapter 7.
Chapter 2  Literature Review

This section surveys related research in the field of serious games. Section 2.1 discusses some of the problems with the traditional teaching methods. Section 2.2 describes why games can be used as an effective educational tool. Section 2.3 gives a brief overview of serious games and lists their essential characteristics. Section 2.4 reviews previous research on application of serious games in the field of Geography. Section 2.5 discusses challenges faced in the game-based assessment and presents techniques used to overcome those challenges.

2.1. Problems with traditional teaching methods

Historically, teaching and assessments in classrooms are mainly focused on the knowledge, transmission, and memorization of facts [3]. Students in most science classrooms have traditionally memorized mathematical formulae, periodic tables, standard definitions, etc. These traditional approaches to learning, however, do not align with current goals of science literacy [17]. Frustration with the current education system is a common motivation for studying alternative ways of teaching. New teaching methods that can keep students engaged and can still provide an authentic view of the learner need to be tested and evaluated [13].
2.2. Why use games?

In the past, computer games were considered a distraction from more useful activities, such as homework or playing outside. Today, however, computer games are an important part of our leisure lives as evidenced from the fact that in 2012, the gaming industry was worth $67 billion [1]. Researchers and educators have proved the ability of games to promote skills such as [18]:

- Strategic thinking
- Planning
- Communication
- Application of numbers
- Negotiating skills
- Group decision-making
- Data-handling

Games are intrinsically motivating and require cognitive and physical engagement of the player. Games allow players to fail, recover, and experiment in the gaming environment [13]. According to Oblinger(2004) [19], games are considered to be potentially powerful learning environments because they provide:

- multi-sensory, active, and problem-based learning
- immediate feedback
- self-assessment through the mechanisms of scoring and level-up options
- social environments involving communities of players
2.3. Understanding serious games

To better understand serious games and how they contribute to learning, it is useful to categorize serious games.

2.3.1. Categories of serious games

There is no accepted standard categorization of serious games; however, the system employed by Herz (1997) [20] is widely used by educators and instructors. The Herz system presents these major categories:

- Action games
- Puzzle games
- Simulation games
- Sports games
- Strategy games

2.3.2. Introduction to simulation games

Simulations are one of the most popular types of games. Laurel (1991) [21] claimed, “Educational simulations (as opposed to tutorial and drill-and-practice forms) excel in that they represent experience as opposed to information. Learning through direct experience has, in many contexts, been demonstrated to be more effective and enjoyable than learning through ‘information communicated as facts’. Direct, multi sensory representations have the capacity to engage people intellectually as well as emotionally, to enhance the contextual aspects of information, and to encourage integrated, holistic responses.”
Simulation games provide the following attractive properties [18]:

- a cheaper alternative to real world training
- instant feedback to players regarding the consequences of their actions
- a safe, virtual environment where dangerous actions can be taken and the consequences of the same can be experienced.

2.3.3. Effectiveness of serious games

Given the benefits of serious games, an increasing number of educators are using games as a teaching tool. Although games are believed to be motivational and educationally effective, the empirical evidence to support this assumption is still limited and contradictory. Kebritchi et al. (2010) [22] present an extensive literature review on the effect of educational games. Their literature review findings are shown in the table below.

<table>
<thead>
<tr>
<th>Literature review</th>
<th>Number of reviewed studies</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Dempsey et al. (1994)</td>
<td>94</td>
<td>Positive effects</td>
</tr>
<tr>
<td>2 Randel et al. (1992)</td>
<td>67</td>
<td>Mixed effects</td>
</tr>
<tr>
<td>3 Hays (2005)</td>
<td>48</td>
<td>Mixed effects</td>
</tr>
<tr>
<td>4 Vogel et al. (2006)</td>
<td>32</td>
<td>Positive effects</td>
</tr>
<tr>
<td>5 VanSickle (1986)</td>
<td>26</td>
<td>Weak positive effects</td>
</tr>
<tr>
<td>6 Emes (1997)</td>
<td>3</td>
<td>No effects</td>
</tr>
<tr>
<td>7 Harris (2001)</td>
<td>2</td>
<td>No effects</td>
</tr>
</tbody>
</table>

Table 1. Literature review on effects of educational games [22].

As can be concluded from the table, all serious games are not effective learning tools. Randel, Morris, Wetzel, and Whitehill (1992) [23] concluded that of 67 studies, 38 showed no differences between the game and conventional teaching; 27 favored games.
The two reviews conducted by Emes (1997) [24] and Harris (2001) [25] found no clear relationship between academic performance and the use of computer games. Based on a review of 48 empirical studies, Hays (2005) [26] found no evidence to indicate instructional games were a preferred method of instruction in all situations. Kirriemuir, et al. (2004) [18], proposed the following probable reasons for the failure of an educational game:

- The game is too simplistic in comparison to other commercial games.
- The tasks are poorly designed and thus quickly become repetitive, boring and ‘work’.
- The range of activities are limited within the game and usually concentrate on one skill.
- The player becomes aware of being coerced into ‘learning’.

2.3.4. Essential characteristics of serious games

To ensure the success of the serious game, it is essential to understand what specific features of games make them effective learning environments. Gee (2009) [27] defined six key properties for good digital games to promote deep learning:

1) An underlying rule system and game goal to which the player is emotionally attached;
2) Micro-control that creates a sense of intimacy or a feeling of power;
3) Experiences that offer good learning opportunities;
4) A match between affordance (allowing for a certain action to occur) and effectivity (the ability of a player to carry out such an action);
5) Modeling to make learning from experience more general and abstract; and
6) Encouragement to players to enact their own unique trajectory through the game.

2.4. Serious games in geography

Given the benefits of serious games, Geography instructors have also started using computer games for geography education. Adams (1998) [28] used SimCity 2000 in an undergraduate, introductory, urban-geography class. The game was used to teach a complex set of issues faced by urban planners. The results showed that one third of students got a better understanding of the difficulties in managing urban funds. Hence, it was concluded that the use of SimCity 2000 enhanced the learning of the introductory urban-geography curriculum. Another example of a serious game used for geographical study is VR ENGAGE developed by Virvou et al. (2005) [29]. The game was used for teaching geography to fourth grade students. The students had to navigate through a virtual environment while answering questions related to geography. To evaluate the educational effectiveness of the VR ENGAGE game, it was compared with another educational software without game characteristics. Results showed that VR ENGAGE was educationally more effective when compared to educational software without game characteristics. It was observed that poor-performing students benefited the most from the game environment.

Tüzün et al. (2007) [5] used Quest Atlantis, a three-dimensional, educational computer game, for teaching world continents and countries to fourth and fifth grade students. Analogous to previous results, pre- and post-achievement tests showed that
students made significant learning gains by participating in the game-based learning environment.

2.5. GeoGame: an online Geography game

The benefits of serious game are evident from the discussion above. Games have also been effective in teaching complex scientific concepts of geography. Despite this, lecture is still the principal teaching mode by Geography instructors [10]. There is a need to develop and explore innovative use of geospatial and gaming technology for teaching and learning of complex geographical concepts. Therefore, GeoGame a web-based, multiplayer, simulation game was developed at The Ohio State University for teaching complex, real-world semantics of the Green Revolution to Geography students.

2.6. Assessment in serious games

Though the advantages of games appear obvious in principle, practical integration of games in teaching and learning is complicated. This section discusses some of the challenges faced in game-based assessment and presents a few techniques used to overcome these challenges.

2.6.1. Game based assessment challenges

When using games as a learning tool, instructors must be able to show that the specified educational goals have been met. As Chen (2005) [30] stated, “It’s not enough to say, ‘games teach’ and leave it at that. Teachers cannot hand out a game to a group of students and assume that they have learned the material.” One main challenge in using games for educational purpose is to make valid inferences about what student learned through games without disrupting the flow of the game [13]. Game flow is very
important as it keeps students engaged. A major advantage of using serious games is that they provide a familiar environment for students. Games are something students relate to and understand. So games that act too much like a classroom, with questions and quizzes interrupt the player's experience.

In their article, Michael and Chen (2005) [30] list the challenges that can make assessment in games difficult:

- Assessment methods used in traditional teaching can't be used in serious games as traditional assessments mainly emphasize fact memorization.
- There can be a wide range of possible solutions to open-ended simulations. Which one is more correct?
- How to assess abstract skills such as teamwork and leadership?

2.6.2. Assessment techniques used in games

This section presents several techniques that can be used to address some of the challenges discussed above starting with discussion of types of assessments based on the purpose.

Assessments can be used for either formative or summative purposes [31]. Formative assessment is designed to provide a constant feedback to students so that they can identify their weaknesses and improve. When used for summative purposes, assessments provide information for activities such as grading or certification. Figure 1 below distinguishes between these assessment styles.
Another way to classify assessments based on the purpose is the student assessment and program assessment. Assessment of student is important to evaluate how good a student is doing in the course. However, it is equally important to evaluate the effectiveness of the course itself [33]. Such evaluation requires identifying and defining the exact needs of the course. Course evaluation helps to improve the execution of the course giving maximum benefits to students [33].

The purpose of the assessment can decide the type of assessment to be used in the game. Michael and Chen (2005) [30] specify three main types of assessments used in serious games:

- Completion Assessment
- In-process Assessment
- Teacher Evaluation

The simplest form of assessment is the completion assessment (i.e., Did the student complete the serious game?) This simple completion criterion could be the first indicator that the student has understood the subject taught.
In-process assessment is analogous to teacher observations of the student as the student performs the task or takes the test. Most of the serious games offer logging and tracking potential that can be used to assist teachers with their assessments of the students.

Teacher evaluation is a combination of both completion assessment and in-process assessment. Serious games should include tools such as homework control, grade tracking, reporting, etc., to assist teachers in their evaluation of students.

2.6.3. Assessment using Information Trails

From the above mentioned assessment techniques, in-process assessment is the most relevant to GeoGame. Loh et al. (2009) [32] have done extensive research on in-process assessment. They term their research as “assessment using Information Trail.” Assessment using information trail works on the supposition that the player actions are determined by his/her decision making process. These decisions are based on player's knowledge of the subject. So it is possible to assess player's problem solving abilities and skills based on players' actions (e.g., speed, accuracy, and strategy) in a learning environment [32].

Information Trails consist of a series of event markers that are deposited within the game. The data collected during these can later be retrieved for analysis. In practice, the game engine triggers events periodically, and as the event is triggered, streams of user actions are recorded (Figure 2). The data collected can be used to find out the most common paths taken by students to reach certain goals. Deviations from the common path could either mean an unusual approach or a wrong approach.
According to Loh et al. (2010) [34] the Information Trails system should be made up of the following components:

1. An online game with user authentication (to facilitate tracking of individual learners).
2. An event listener or a trigger for the data collection processes.
3. A database server to facilitate data collection and record keeping.
4. A component to visualize the data as useful information.

Chapter 4 describes specific parts of the assessment techniques, discussed in this Section, that are used in the GeoGame.

2.7. Persuasion theory

As mentioned earlier, games can be used to change fundamental attitudes and beliefs. Such games are called 'persuasive games'. GeoGame is a persuasive game designed to change the student’s attitude towards farming in developing countries. The primary reason why games can be effective in persuasion is because the player is
intrinsically motivated to play the game. For effective implementation of a persuasive game, understanding the principles of human psychology and motivation is paramount. Chapter 5 presents some of important persuasion theories, which are the building blocks of the persuasion aspect of GeoGame.
Chapter 3  GeoGame Architecture

This chapter describes the architecture of the game. First, a brief overview of the game and the basic idea of the game play is provided. Next, requirements of the application, as presented by the stakeholders are identified. Then, architectural decisions taken to satisfy those requirements are presented. Further, the architecture of the game using static and dynamic views of subsystems are described. Finally, the turn change module which is a critical component of the architecture is described.

3.1. Game concept

GeoGame is a web-based, multiplayer, simulation game which uses geospatial information and gaming technology for teaching the complex real world semantics of the Green Revolution. GeoGame is built on the board game conceptualized by Ricardo Salvador at Iowa State University [35]. The project is funded under an NSF-EXP grant.

GeoGame is designed to supplement classroom instruction on the Green Revolution in an undergraduate general education course on world regional geography. This course introduces students to different regions and provides a means of understanding them. The lectures emphasize historical-geographic processes like development, globalization, migration, regional integration, and environmental change. Though lectures and assignments enable students to gain knowledge of the Green Revolution, they do not give them an opportunity to apply their understanding in real
world situations. While playing GeoGame, students are put into situations where they have to apply their understanding of the Green Revolution and make decisions based on the geographic location of the farmland. To create such an environment, GeoGame uses online maps with geo-processing capabilities. Geo-processing means automation of GIS tasks which manipulate spatial data [36]. Common examples of GIS tasks are calculation of distance between land parcels, augmenting new data on the online map etc.

3.2. Game description

Before going deep into the requirements and architecture of the game, an understanding of how the game is played is necessary.

Figure 3. Game description.
A player adopts the role of a farmer in a rural household that grows wheat (Figure 3). Every player has a family with some family members (adults and children). The aim of a player is to satisfy the consumption needs of the family and increase his/her wealth. If the consumption needs are not met, then the family loses one of its family members starting with the youngest one.

The game is divided into turns where each turn represents one growing season. Every player is given some initial land and money. Using this money, a player can buy more land and assets, and cultivate the land. The yield of the land depends on number of factors like irrigation level, type of seeds used, fertilization level, and weather conditions. During a turn, a player trades assets like seeds, oxen, fertilizers, labor, etc., with other players or with the bank. Players make strategic decisions such as setting up irrigation cycles, deciding the amount of fertilizer to be used, etc.

At the completion of each turn, the system calculates total consumption and yield of a family. In addition, after each turn the game announces the drawing of a “fate-card”, an element of the game reflecting real-world events (e.g., the birth of a child, a pest attack on grains, arrival of relief organizations offering farming equipment at low prices, etc.) At any point of the game, a player can view a scoreboard to see how much extra wealth the new technology has generated in the village.

A detailed description of the game and game rules can be found in Appendix A.

3.3. Requirements and architectural decisions
To decide technologies to be used in a game, it is important to identify requirements of the game. Both functional and non-functional requirements of the game will be discussed.

3.3.1. Functional requirements

Functional requirements capture specific intended behavior of the system being developed. These requirements describe what the system is supposed to do. Following are the functional requirements of GeoGame:

- Geospatial processing: A visual map provider with standard GIS geo-processing capabilities.
- User authentication
- Game creation and joining
- Asset trading with other players and with the bank
- Farmland development (i.e. plant, fertilize, and irrigate a land parcel)
- Player communication via a forum
- Scoreboard lookup to get the current status of every player in the game

3.3.2. Non-functional requirements

Non-functional requirements impose constraints on the design. These requirements specify how a particular functionality should be implemented. The non-functional requirements include,

- Flexibility - a framework for flexible and rapid web development to build scalable and easy to maintain web applications.
- Usability - client side technologies for rich and easy to develop user interface
- Persistence - a standard database management system
- Scalability - easy to scale client-server architecture
- Performance - real time web functionality with Server-Side push

3.3.3. Architectural decisions

To meet the above requirements, a few architectural decisions were made. Figure 4 shows the requirements along with the technologies used to meet those requirements.

Figure 4. Architectural decisions.

- ArcGIS is a GIS that allows static maps to be hosted online as a web service. An ArcGIS server was chosen over other generic map services because it offers standard geo-processing with a high degree of customizability. It also provides a
JavaScript API that allows full interaction and manipulation of all of the map’s data layers from within any web page or application [37]. Windows server was chosen to run the web application because ArcGIS server tends to run faster and integrates well with the windows server [38].

- ASP .NET MVC3 framework was selected for rapid and flexible web development. Model-View-Controller (MVC) is a design pattern that allows clear separation of concern and test driven development [39]. A model represents the state of the application. A controller handles interactions and updates the model to reflect a change in the state of the application, and then passes information to the view. A view accepts necessary information from the controller and renders a user interface to display that information [39]. ASP .NET MVC3 is a web development framework which implements MVC design pattern. ASP .NET MVC3 provides an integrated scaffolding system, that generates basic web applications with user authentication enabling rapid web development. Another important reason for choosing ASP .NET MVC3 framework was that the ArcGIS server JavaScript API can be easily coupled with the framework [40].

- REpresentational State Transfer (REST) architecture was selected for building scalable client server architecture. REST relies on a stateless, client-server, cacheable communications protocol. Because of their stateless nature, REST applications are scalable. REST architecture is well supported by the ASP .NET MVC3 framework. Uniform Resource Locator (URL) mapping component of the
ASP.NET MVC3 framework supports URL naming pattern that works well with the REST addressing [39].

- HTML5, AJAX, JavaScript and jQuery were chosen as client side technologies since these allow for rich and easy user interface (UI) development. HTML5 is a new version of HTML which has a rich support for graphic and media content. It has better page structure, better form handling, geolocation support, and the application cache [41]. JavaScript is a scripting language popularly used for validating forms and communicating with servers. ASP.NET MVC3 provides an easy integration with JavaScript frameworks [39]. ASP.NET MVC3 along with the REST architecture has a good support for AJAX technology specially using jQuery [42]. AJAX provides a way to communicate with the server and update parts of a web page without reloading the whole page. jQuery is a JavaScript library which provides an easy-to-use APIs for event handling, AJAX calls, form validations and animations [43].

- ASP.NET SignalR was selected to provide real-time web functionality with server side push. In a multiplayer setting, it is important to update the gaming environment of every player on any game event. ASP.NET SignalR is a library that allows the ASP.NET application to push content to connected clients instantly as it becomes available.

3.4. GeoGame architecture

This section explains the architecture of the game using static and dynamic interactions of the subsystems.
3.4.1. Server interactions

Before going into the subsystems, it is important to understand how different servers interact with each other within the game. There are three different servers that communicate with each other and with the client machine: a web server, an ArcGIS server, and a database server. Figure 5 describes a dynamic view of the server interactions.

![Dynamic view of server interactions](image)

Figure 5. Dynamic view of server interactions.
As illustrated above, the client machine sends a request for a game specific map to the ArcGIS server. The ArcGIS server then fetches farmland details from the database server and renders a map on the client machine. To perform a game-specific action, the client machine sends a request to the web server. If the web server requires geospatial information to service that request, it communicates with the ArcGIS server. After servicing the request, the web server reports any changes made to the database server. Since the ArcGIS server and the web server share the same database server, any changes done by one become accessible to the other immediately.

3.4.2. Subsystems and contracts

Figure 6 shows subsystems within the game and contracts between them. Every subsystem can be tied to a functional requirement listed in Section 3.3.1.
The User Manager subsystem manages user authentication and provides user credentials to other subsystems. The Forum Manager enables players to communicate with each other. GIS System handles all geo-processing requests and provides geospatial data to the Game Manager. The Game Manager implements the game logic and enables players to create and join a game, as well as plant, irrigate, and fertilize a farmland. The Game Manager also manages the turn-change function which will be discussed in detail in Section 3.5. The Market Manager enables a player to trade assets with other players and with the bank. The Market Manager also handles transaction requests sent by the Game Manager. The Data Logger subsystem logs all game events. Logged events can be retrieved later to display the scoreboard and for the purpose of analysis. The Assessment
System monitors all game events and asks pre-defined questions to players. The Assessment System is discussed in detail in Chapter 4.

3.4.3. Dynamic view of subsystem interactions

Figure 7 shows how subsystems interact at runtime. Figure 7 depicts a scenario where the player first creates a game, then trades assets with the bank, and lastly, plants seeds in the land.

To create a game, a player needs to login to the system. The login request is sent to the User Manager. After authenticated by the User Manager, the player sends a 'create game' request to the Game Manager. The Game Manager communicates with the User Manager to verify the user’s credentials. Since GeoGame uses a stateless architecture (REST), every request is considered to be separate. Hence, before servicing a request, every subsystem has to communicate with the User Manager for authentication. This communication is not shown in the figure due to space constraints.
Once a proper authentication is accomplished, the Game Manager creates and initializes the game. At this point, the Game Manager sets up the turn. Turn setup
includes tasks like initializing a timer, drawing a Fate card, and setting up new asset prices. All these functions are performed every time a turn change occurs.

As per the example, the player decides to trade assets with a bank or with other players. Any trading request is sent to the Market Manager. The Market Manager services the request and updates assets of the player, then reports the transactional data to the Data Logger for logging purposes. The Market Manager also reports the market event to the Assessment System to check if any questions are configured for that market event. If there are questions configured, then they are presented to the player, and player's responses are captured.

After trading assets the player then decides to plant seeds in a parcel. The plant request is sent to the Game Manager. The Game Manager follows the same process followed by the Market Manager to service the trade request. The Game Manager first services the request and updates the parcel data, then reports the game event to the Assessment System to check if any questions are configured for that game event. Any request sent to the Game Manager or the Market Manager goes through the same path. As mentioned in the turn setup, the Game Manager initializes a timer to mark the start of a turn. When that timer expires, a turn change is triggered by the Game Manager. The Game Manager performs activities like calculating the total yield, killing a family member (if the consumption exceeds the yield), and increasing the age of all family members by one year. These activities are performed upon every turn change.
3.5. Turn change module

The turn change module is the most critical components of the game architecture requiring detailed discussion. As previously mentioned, the game is divided into turns where each turn represents one growing cycle. The turn duration is configured when the game is created and is fixed throughout the game. There are two ways in which turn change can occur: 1) a timer triggered turn change, and 2) a manual turn change. When a turn starts, a timer is set for a turn duration. When this timer expires, a turn change is triggered. This is referred to as the timer triggered turn change. A manual turn change occurs when all players decide to move to the next turn before the timer expires. Every player is given a turn change button. Once a player is done playing the turn, he/she clicks on the turn change button. This marks that the player is ready for the turn change. A turn change occurs only when every player in the game is ready for the turn change. Different scenarios arise because of these two ways of turn change making it challenging to implement in the multiplayer environment.

3.5.1. Server polling

The easiest way to implement turn change is through polling, but polling affects the system performance. Consider a scenario where there are three players (e.g., P1, P2, and P3). Suppose P1 clicks on the turn change button. Since P2 and P3 are not ready for the turn change, turn change can't occur. Now P1 has to continuously check with the server if the turn change has occurred at the server side. Now suppose P2 clicks on the turn change button. Again turn change can't occur because P3 is not ready for a turn change. So P1 and P2 both have to send requests to the server to check if the turn change
has occurred. This is called server polling, and polling hampers system performance.

Once P3 clicks on the turn change button, turn change occurs, and P1 and P2 stop server polling. Figure 8 shows how server polling is implemented.

![Server polling diagram](image)

**Figure 8. Server polling.**

3.5.2. Server side push

An efficient way to implement turn change is the server side push. As the name suggests, server side push technology allows the server to push contents to a client without the client sending a request to the server.

Consider that same scenario with the three players. P1 clicks on the turn change button. Turn change doesn't occur because P2 and P3 are not ready for the turn change, but P1 now sits idle and doesn't send any polling request to the server. P2 clicks on the turn change buttons and sits idle, too. Now when P3 clicks on the turn change button, the
server recognizes that all players are ready for the turn change, so the server pushes the turn change event to all three players. This method saves lot of precious server cycles as the server doesn't have to service any client polling requests. Figure 9 shows how server side push is implemented.

![Server side push diagram](image)

Figure 9. Server side push.

Server side push is implemented in GeoGame using ASP.NET SignalR technology. ASP.NET SignalR is a library for ASP.NET developers that allows server side push to connected clients and simplifies the process of adding real-time web functionality. ASP .NET SignalR uses web sockets to enable bi-directional
communication between the browser and server [44]. Web socket defines a full-duplex single socket connection over which messages can be sent between client and server [45].
Chapter 4  Assessment System

In the last few years, serious games have gained a lot of attention because of the active learning environment they provide. Students learn by direct application rather than through information communicated as mere facts. Researchers have lauded games for their ability to promote problem solving, communication, and collaboration. Though the advantages of serious games appear obvious, games have not been effectively used in the educational setting [22]. One major reason for that is the assessment of students in the game-based learning has been difficult. As discussed in Section 2.4.1, it is difficult to make valid inferences about what students learn through games without disrupting the flow of the game. This chapter describes how student assessments are done in GeoGame and how GeoGame uses some of the assessment techniques mentioned in Sections 2.4.2 and 2.4.3.

4.1. Assessment in GeoGame

GeoGame is designed to supplement classroom instructions on the Green Revolution in an undergraduate general education course on world regional geography. The game is played at the end of the course to test specific knowledge about the Green Revolution. The goal of GeoGame is to give students a better understanding of the challenges faced by farmers in developing countries. For example, students should understand the agricultural benefits gained through the introduction of high-yield seed
and better irrigation, and at the same time appreciate the economical challenges that a farmer may face at the individual, household level.

In GeoGame, players have to make a number of strategic decisions about where to invest money, how to maximize profit, when to trade assets, etc. This process of applying subject knowledge to make strategic decisions in real-world situations, is a form of active learning. Here the important features of performance are not simply right or wrong, but are effective and efficient strategic decisions. In other words, it is important to verify if a student is making any conscious decisions as opposed to just random decisions. One way to verify conscious decisions is to gauge the thinking process behind the decisions made by a student. GeoGame uses in-game questions to gauge the thinking process of a student. Students are asked pre-defined questions on certain game events which they have to answer to proceed further. This is a type of in-process assessment as discussed in Section 2.4.2.

As described in Section 2.4.3, Loh et al. (2009) [32] have done extensive research on the in-process assessment technique. They term their research as 'assessment using Information Trail'. In this type of assessment, player specific information is captured at certain event markers, and that information is used later for data analysis. Figure 10 shows a logical representation of the GeoGame assessment system analogous to the one described by Loh et al. (2009) [32].

An event can be any game event such as buying high yield seeds, fertilizing a land parcel, selling harvested grain, etc. The system stores the student's responses to questions
as player specific information. These responses are later retrieved and analyzed by the instructor to evaluate the success of the game.

Figure 10. Components of Information Trail.

Questions asked on game events are defined and configured by the admin user. The admin user may not want to ask questions on every occurrence of an event as that can disrupt the flow of the game. Hence the assessment system should allow an admin user to specify certain conditions, which need to be checked before the questions are asked. For example, "if a player buys high yield seeds, and he/she had bought low yield seeds in the last turn, then ask a certain set of questions". Here the condition is 'if the player had bought low yield seeds in the last turn'.

Consider a scenario where there are number of conditions defined for a single game event 'turn change'. The admin user may want to ask questions A,B for turn 1 and questions C,D for turn 2. In that case, the admin user will specify condition 1 as 'if game
turn is 1’ and will configure questions A,B for condition 1. Similarly the admin user will specify condition 2 as 'if game turn is 2' and configure questions C,D for condition 2.

When a turn change event occurs, the system should check condition 1. If that evaluates to true, then the system should populate questions A,B. If condition 1 evaluates to false, then the system should check condition 2, and populate questions C,D if condition 2 evaluates to true.

Based on the above discussion, requirements of the assessment system in GeoGame can be summarized as follows:

- The admin user should be able to select any game event on which he/she wants to ask questions.
- The admin user should be able to configure a set of questions to be asked on the selected game event. System should provide an easy way to configure the questions.
- The admin user should be able to specify complex conditions which the system should check before the questions are asked. Admin user should be able to change these conditions easily.

4.2. Assessment system architecture

The GeoGame assessment system uses different technical innovations to effectively implement all the features mentioned above. Figure 11 shows architectural decisions taken to satisfy requirements of the assessment system.
The first requirement of an assessment system is that the admin user should be able to ask questions for any game event. Every game event has its own method for servicing that request and returning a response. Adding a new functionality to that flow requires significant code changes. The assessment system can avoid code changes by using the interceptor design pattern. Interceptor is a software design pattern that is used to change, or augment, new information within the normal processing cycle of the software system [46]. Interceptors extend the current server side processor to perform new functions without modifying any existing code. In geogame, interceptor augments questions on the server response. This makes the assessment system easy to maintain and modify.
• Augmenting a question list on the server response creates a new requirement. Since every response has its own response handler, the question list needs to be separated from the original response. The JavaScript Object Notation (JSON) handler performs that task. The JSON handler creates a wrapper for both the question list and request response. At the server side, the JSON handler wraps a request response and question list together to create a single JSON response and sends it across to a client. At the client side, the JSON handler unwraps the JSON response and separates the question list from the request response. Separating out such common functionality into a module makes the architecture more modularized.

• The second requirement of the assessment system is an ability to specify complex conditions. Handling every possible condition via a series of the usual conditional statements becomes too complicated. So the assessment system uses a web rule engine to easily configure complex conditions. The Web Rule Engine [47] is an ASP.NET MVC server component that allows creation, modification, validation, and evaluation of complex business rules. The rule engine separates out conditions in the business rule form instead of embedding them within a program. These business rules can be configured by the admin user without a developer having to write new code for every new condition.

• The web rule engine comes with a rule editor to create, edit, save, and delete rules. The rule editor provides IntelliSense support which makes it easy for an
admin user to specify rules. IntelliSense is an auto completion feature which populates condition variables to avoid syntax errors.

- The third requirement of the assessment system is to allow the admin user to easily configure questions using an admin module. The admin module provides a rich and user friendly interface. The admin module schema is designed in such a way that it avoids redundancy and ensures maximum reuse.

These modules will be discussed in detail later in this chapter. First consider the dynamic view of assessment subsystem interactions (Figure 12).

The typical flow of the system is as follows:

- A client sends an AJAX request to any REST endpoint of the game manager.
- At the server side, the game manager services the request and returns a response.
- That response is intercepted by the interceptor. The interceptor extracts the action name from the response and sends it to the action mapper.
- The action mapper maps that action name to an action ID. The action mapper now has to check two things. First, it needs to check if there is at least one set of questions configured for that action ID. To check that, the action mapper sends a request to the admin module. The admin module returns a question flag which can be either true or false. If the question flag is true (i.e., there are questions configured for that action ID), then the action mapper needs to check if the current player object satisfies any of the configured conditions (or rules). The action mapper then calls the rule evaluator to execute the rules.
Figure 12. Dynamic view of assessment system interactions.
• The rule evaluator communicates with the admin module to fetch a list of rules configured for a particular action ID. It then evaluates the current player object against those rules, and if any rule evaluates to true, the rule evaluator calls the admin module to fetch the list of pre-configured questions for that rule.

• This question list is then returned to the action mapper which eventually returns it to the interceptor. At the interceptor, the JSON handler wraps the original response and the question list into a single request. This consolidated request is then sent to the client.

• At the client side, the JSON handler unwraps the JSON response and separates the question list from the request response. It then sends the request response to the original response handler and the question list to the question handler.

There are three main parts in the architecture:

• Interceptor
• Rule engine
• Admin module

4.3. Interceptor

GeoGame implements the interceptor design pattern using filters provided by the ASP.NET MVC3 framework. Filters are custom classes that offer programmatic means for adding pre-action and post-action behavior to controller action methods [48]. The assessment system overrides an OnActionExecuted method to add post-action behavior. The OnActionExecuted method is automatically called by the framework after the controller action executes.
4.4. Rule engine

A rule engine is a mechanism for executing 'business rules'. Business rules are business-oriented statements that encode business decisions in a simple if/then conditional form [49]. The rule engine is used by an admin user to define complex conditions in the form of rules that are executed before asking preconfigured questions. The assessment system uses the web rule engine as it can be easily embedded in an ASP.NET MVC web application. The web rule engine is a server component that allows for creation, modification, validation, and evaluation of complex business rules.

Use of a web rule engine requires three essential steps. First, decide the source object. The assessment system uses a family object as a source object because all possible conditions can be defined using a family object. Second, create business rules. The web rule engine provides an easy to use rule editor to create, edit, save, and delete rules [47]. In GeoGame, the admin user uses this rule editor to specify the complex conditions. The third step is the evaluation of the business rules. The web rule evaluation engine is capable of evaluating millions of source objects against a rule in a matter of milliseconds [47].

4.5. Admin module

The admin module allows the admin user to configure the question list for any game event. The admin module provides the following functionality to the admin user:

- Add/Edit/Delete a question list for a particular game event.
- Specify order of questions in the question list
- Add/Edit a condition using the rule editor provided by the web rule engine
- Activate or deactivate a rule

![Admin module DB schema](image)

Figure 13. Admin module DB schema.

The database schema of the admin module (Figure 13) is designed in such a way that it avoids redundancy and ensures maximum reuse. As shown in the figure, the Options table stores individual options for a multiple-choice question. The OptionGroup table groups the number of options in a single reusable set. The Questions table stores individual questions, whereas questionList table stores the order of questions in a list. The QuestionGroup table groups individual questions along with their order into a single set which can be reused.

The admin module provides a interface for the admin user to configure questions and conditions. The user interface is designed to provide a satisfactory user experience.
Figure 14. Admin screen with rule editor

Figure 14 shows one of many interfaces developed for the admin module. This interface allows the admin user to configure the question list. It also allows the admin user to specify a complex condition using the rule editor.
Chapter 5  Persuasion Aspects of GeoGame

This chapter describes the persuasive aspects of the game. It mainly focuses on the motivation aspect of persuasion. First, a few important persuasion theories, which are the building blocks of the persuasion aspects of GeoGame, are discussed. Next, a few features that have been shown to improve player motivation in the game, are described. And lastly, a detailed description of persuasion features implemented in GeoGame are presented.

5.1. Persuasive games

In Chapter 2, how games can be used for more than just entertainment was discussed introducing the term 'Serious Games' signifying games that teach. However, games can do more just teach. Contemporary research has shown that games can be used to change fundamental attitudes and beliefs leading to a significant long term social change [14]. Such games are called 'persuasive games'. The main aim of GeoGame is make students understand how difficult farming in developing countries can be. This attitude shift is the primary reason why GeoGame is being developed. Hence, GeoGame is a persuasive game, a special kind of serious game.
5.2. Persuasion theory

This thesis is a part of an ongoing research on persuasive applications in CERCS for Enterprise Transformation and Innovation (CETI)\(^1\). CERCS stands for Center for Experimental Research in Computer Systems. For effective implementation of a persuasive game, understanding the principles of human psychology and motivation is paramount. In this section some of the fundamental theories of persuasion are discussed, focusing mainly on the motivation aspect of persuasion.

5.2.1. Intrinsic vs. Extrinsic motivation

Ryan and Deci (2000) [50] define two type of human motivations: Intrinsic motivation and Extrinsic motivation. Intrinsic motivation is the motivation driven by an interest in, or enjoyment of, the task itself. Extrinsic motivation refers to an outcome based performance. Extrinsic motivation is based on some external factors (e.g., award, money, grades, etc.). Intrinsic motivation is very effective for persuasive communication, but it is very difficult to achieve. The primary reason why games can be effective in persuasion is because the player is intrinsically motivated to play the game. The player gets immersed into the game so much that he/she loses track of time. Such an immersive environment is very effective for the long-term attitude shift. However, not all educational games can create such an environment.

\(^1\) http://www.ceti.cse.ohio-state.edu/
5.2.2. Self Determination Theory

Self Determination Theory is a theory of human motivation and personality developed by Edward L. Deci and Richard M. Ryan [15]. Many researchers and educators have used this theory to create persuasive, intrinsically motivating games.

According to this theory, humans have innate psychological needs which are the basis for self-motivation. There are three innate needs: Autonomy, Competence, and Relatedness.

Autonomy means an ability to take your own decisions independently. Competence signifies experiencing mastery over something. Relatedness denotes an urge to interact, connect, and care for others. In the gaming context, these needs mean the following:

- Autonomy means an ability to choose from a number of available options within the game. Players feel motivated to try out different options and experience the consequences of the same.

- Competence means to experience mastery and a sense of growth while playing the game. Players feel motivated only if the game is neither too easy nor too difficult. If the game is too easy, then players don't feel the sense of growth; and if the game is too difficult, then players get frustrated and stop trying. Games should create what is called a 'pleasurable frustration' [16]. According to the 'self efficacy theory' proposed by Albert Bandura (1997) [51], if a player feels that he/she can achieve the goal, then he/she will try harder and longer. This kind of pleasurable frustration creates a stress called 'eustress', stress that is deemed
healthful or giving one the sense of fulfillment, thus maintaining the player’s motivation [13].

- Relatedness is the feeling of doing something together. Emotional engagement with other players, be it a human or a computer character, motivates players to play the game.

If a game implements features on the basis of these three innate needs, then players feel intrinsically motivated to play the game; and such a game can be used to achieve a long-term attitude shift (i.e., persuasion).

5.2.3. Elaboration Likelihood Model (ELM) of persuasion

Elaboration Likelihood Model [52] provides a generic framework for understanding basic processes that govern the effectiveness of persuasive communication. There are mainly two routes of persuasion: central and peripheral (Figure 15). In the central route, the person being persuaded actually thinks about merits and the relevance of the presented information; whereas in the peripheral route, persuasion is achieved through peripheral cues rather than issue-relevant arguments. Some examples of peripheral cues are expert source, number of arguments, etc. The student’s ability and motivation decide which route of persuasion is to be taken. If a student has an ability and motivation, then the central route is to be taken where more issue-relevant arguments can be added to the persuasive communication. However, if the student lacks motivation or ability, then the peripheral route is the preferred route.

In the context of persuasive games, issue-relevant arguments mean features that increase the complexity of the game. Such features add more game play and are aligned
to the educational goals of the game. For persuasive games, peripheral cues are the features that can increase player motivation (e.g., score, badge, level up, etc.). These features are external to the game play and need not be aligned to the educational goals. Such features are only meant to increase the player’s engagement with the game.

![Figure 15. Elaboration Likelihood Model.](image)

5.3. Persuasion in GeoGame

As discussed earlier, GeoGame is a persuasive game designed to change the student’s attitude towards farming in developing countries. The first version of the game was developed and tested using a few students in the Fall of 2012. Details of the evaluation will be presented in the next chapter. The evaluation of user testing showed that students lacked emotional engagement in the game, and thus, were not motivated to
play the game. According to ELM theory, the peripheral route for persuasive communication is indicated. Hence, focus turned to the motivational aspect of persuasion. Therefore, new features were added to the second version of the game to increase the player's motivation to play the game.

5.3.1. Persuasion features that increase player motivation

Based on the research presented by Annetta et al. (2011) [16], a list of features that might increase player motivation was created. Below are the features considered.

- **Level Up Option**
  
  In Section 5.2.2 we discussed competence as one of the innate needs. We also discussed the theory of self-efficacy. Games can increase self-efficacy by constantly rewarding players. The level up feature is one way to reward a player. The level up option gives a player a sense of mastery by completing a level and motivates him/her to keep trying for the next level.

- **Group Goal**
  
  Relatedness is one of the innate needs as per the Self Determination Theory. To create a sense of cooperation, games can include a group goal. Such a group goal increases interaction and communication between players. Players feel a need to collaborate with others to achieve an objective. This creates a sense of belonging between players, thus motivating them to play the game.

- **Non-Player Character**
  
  Another way to increase relatedness in the game is to add a computer character to guide players. Players get emotionally involved in the character as it helps them to
achieve their goal. Feedback from the non-player character can be an
educationally relevant message.

- **Player Avatar**

An avatar represents the player's identity through a unique character. Such a
character representation allows players to engage in the process of identity
exploration. Avatars convey a player’s identity, presence, location, and activities
to other players [53].

According to the study conducted by Annetta and Holmes (2006) [54], avatars
increase social presence and build a sense of identity. Their study showed that
students who had a choice of avatar had a greater course satisfaction than students
who had to choose between a standard male or a female icon. Students who had a
choice of avatar felt closer to their classmates and instructor.

5.3.2. **Features implemented in GeoGame**

We implemented two new features to increase the players' emotional involvement
in the game:

- An ability to select a player avatar, and
- An ability to name family members.

As shown in Figure 16, each player has to select his/her avatar from a grid of
avatars. To make avatars realistic, avatar pictures were selected to represent a farmer, or a
farmer family, in India.
Once a player selects an avatar from the grid, it becomes the identity of that player. That avatar is displayed on the game screen and the scoreboard along with the player name.

In addition, a feature that allowed players to name their family members was added. This name is used to address a family member. For example, suppose that family member named "Gopal" dies of starvation; then a message stating, "Gopal died of
starvation" is shown to the player instead of a message stating, "Family member died of starvation." This can increase the player’s emotional involvement with the game, and the player can better identify himself/herself with the game family. Thus, at the beginning of the game, the player must select his/her avatar and name his/her family members.

To evaluate the effectiveness of these persuasion features, well-designed user testing was conducted. A few sets of players played with the persuasion features enabled, and few played with the persuasion features disabled. Therefore, a flag was added to enable or disable these features. The results of user testing will be presented in the next chapter.
Chapter 6  Results and Evaluation

This chapter presents the results of user testing for evaluating the success of GeoGame. First, the user testing procedure is described, followed by an analysis of the user testing conducted in the Fall term of 2012. After improvements were added in the second version of the game, another user testing was performed in the Spring term of 2013. Finally, the effectiveness of the persuasion features is examined.

6.1. User testing design

GeoGame is designed to supplement classroom instruction on the Green Revolution in an undergraduate general education course on world regional geography at The Ohio State University. The game is integrated into the classroom as a homework assignment. The first set of user testing was performed in the Fall semester of 2012. Based on feedback from users, new features were added in the game, and the second version of the game was released. Version 2 was then play tested in the Spring semester of 2013.

Students signed up for the game towards the end of the semester when they were then assigned credentials enabling them to play a few practice games. At this point students were randomly assigned into the game in groups of 4-5 players each. Every game consisted of seven turns with one turn lasting a day. Therefore, one game spanned a week's duration. Throughout the game students were asked in-game questions. Usually
the questions were asked at the turn change event. At the beginning of the last turn, students took a voluntary survey.

In the survey, students were asked to rate the game on the following parameters:

- Concentration in the game,
- Workload imposed by the game,
- Feedback from the game,
- Game interface,
- Social interaction promoted by the game,
- Emotional involvement in the game.

Rating was done on a scale of 1 to 5 with 1 being poor and 5 being good.

Responses to the in-game questions and survey questions were analyzed to evaluate the effectiveness of the GeoGame as an educational tool. Details of the in-game questions and survey questions can be found in Appendix B and C, respectively.

6.2. Evaluation of version 1

A total 151 students signed up to play the game in the 2012 Fall semester. Out of these 151 students, 112 students played at least one turn of the game. Of these 112 students, 79 students responded to the voluntary survey.

Out of the 79 students who took the survey, 49 were male, and 30, female. Broken down by class 36 were freshmen; 22 sophomores; 17, juniors; and, 4, seniors. To better understand the population distribution, students were asked to rate their familiarity with online maps, GIS software, and computer games. Table 2 shows the distribution of the user population.
The table shows that most players were familiar with online maps and unfamiliar with the GIS Software. Table 2 also shows that there was a fairly even distribution of players in terms of their familiarity with the computer games.

6.2.1. Analysis of the post game survey

As described in Section 6.1 students were given a voluntary survey to rate the game on various parameters. Figure 17 shows the analysis of the student ratings.

![Figure 17. 2012 Fall semester survey results.](image)
The parameters on which the game was rated are indicated on the X-axis of the graph; the number of players per rating, on the Y-axis. Three parameters received a Good rating: Workload, Feedback and Interface. The game got an Average rating on Concentration and Social Interaction. However, significantly the Emotional Involvement parameter received a Poor rating.

6.2.2. Attitude shift

As discussed in Chapter 5, GeoGame is a persuasive game designed to change the student’s attitude towards farming in developing countries and make students understand how difficult farming can be. To evaluate how successful the game was in the persuasion arena, students were asked to give their opinion on the following statement:

"Farming in developing countries is hard work, but farmers can still have some measure of success." Students were given five options: Strongly Agree, Agree, Neutral, Disagree and Strongly Disagree.

Students were asked the same question in the first turn and after the last turn. The responses of the students indicated their opinions before playing the game and after playing the game. Any shift from agreement (in the first turn) to disagreement (in the last turn) was considered as a positive attitude shift; whereas any shift from disagreement to agreement was considered as a negative attitude shift. For example, suppose a student strongly agreed to the statement in the first turn, but responded as 'agree' in the last turn; then, it was considered a positive attitude shift.
Figure 18 shows how effective GeoGame was in changing students’ opinions about farming in developing countries. A total of 94 students responded in both the first turn and the last turn.

![Attitude shift towards farming in developing countries](image)

**Figure 18.** Attitude shift towards farming (2012 Fall semester).

It can be observed from the graph that a large number of students did not change their opinion. However, more students had a positive attitude shift than a negative attitude shift. This shows that the game gave students a better understanding of how challenging farming in developing countries can be.

6.3. Improvements in version 2

Based on the feedback received from the students in the 2012 Fall semester, three new features were added to the second version of the game. Version 2 was rolled out in the 2013 Spring semester.
As discussed in Chapter 5, two features were added to improve the student’s emotional involvement in the game (persuasion features)

- An ability to select a player avatar, and
- An ability to name family members.

It should be noted that not all students played the game with the above features. A few students played with these features disabled; and a few played with these features enabled. This was done to analyze the effect of the features.

A third feature, added in Version 2 of the game, was an ability to build an irrigation duct. This feature was enabled in all games of the 2013 Spring semester. In Version 1 of the game (play tested in the 2012 Fall semester) players bought water (to irrigate a parcel of farmland) from the bank. However, in reality farmers have to build irrigation ducts to irrigate their farmland. This real world process was simulated in the game by adding the irrigation duct feature. The cost of an irrigation duct depends on the distance of the farmland from the water source. Geo-processing capabilities of the ArcGIS server are used to calculate the distance between the farmland and the water source.

As was done for Version 1, the effectiveness of the new features, and the game in general, was evaluated by conducting well-designed user testing in the 2013 Spring semester.
6.4. Evaluation of version 2

A total 150 students signed up to play the game in the 2013 Spring semester. Out of these 150 students, 74 students played at least one turn of the game. Of these 74 students, 54 students responded to the voluntary survey.

Out of 54 students who took the survey, 19 were males and 35 were females. Broken down by class 10 students were freshmen; 23, sophomores; 12, juniors; and, 9, seniors. To understand the population distribution, students were asked to rate their familiarity with online maps, GIS software and computer games. Table 3 shows the distribution of the user population.

<table>
<thead>
<tr>
<th>Scale</th>
<th>Online Maps</th>
<th>GIS Software</th>
<th>Computer Games</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (never used)</td>
<td>0</td>
<td>30</td>
<td>4</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>12</td>
<td>15</td>
</tr>
<tr>
<td>3</td>
<td>12</td>
<td>7</td>
<td>14</td>
</tr>
<tr>
<td>4 (used frequently)</td>
<td>21</td>
<td>5</td>
<td>9</td>
</tr>
<tr>
<td>5 (used frequently)</td>
<td>20</td>
<td>0</td>
<td>12</td>
</tr>
</tbody>
</table>

Table 3. Population description from the 2013 Spring semester.

The table shows that most players were familiar with online maps and unfamiliar with GIS Software. Table 3 also shows that there was a relatively even distribution of players in terms of their familiarity with computer games. This distribution is analogous to the 2012 Fall semester user testing population.

6.4.1. Analysis of the post game survey

Figure 19 shows the analysis of students' responses to the post game survey.
The parameters on which the game was rated are indicated on the X-axis of the graph; the number of players per rating, on the Y-axis. Three parameters received an average rating: Concentration, Workload and Feedback. The game also received a poor rating in three other parameters: Interface, Social Interaction and Emotional Involvement. These results are not exactly analogous to the 2012 Fall semester results. There was no apparent reason found for such results.

6.4.2. Attitude shift

Similar to the 2012 Fall semester user testing, students were asked their opinion on farming in developing countries before and after the game. Students' responses were analyzed to evaluate the success of the GeoGame in changing attitudes. Figure 20 shows how effective GeoGame was in changing students’ opinions. It should be noted that in
the 2013 Spring semester user testing, a majority of students could not answer the assessment questions in the first turn because of a technical issue. As a result, only 24 students responded in both the first and last turn.

Figure 20. Attitude shift towards farming (2013 Spring semester).

It can be observed that significantly more students had a positive attitude change than negative. This shows that the game was successful in changing players’ attitudes.

6.5. Effect of persuasion features

This section presents evaluation of the persuasion features tested in the 2013 Spring semester. Persuasion features were added in a systematic manner. First, around 120 students played the game without persuasion features. Then, persuasion features were implemented with 30 students playing with the persuasion feature enabled. Responses of these two populations are analyzed and compared.
As mentioned in the Section 6.2, students took a voluntary survey at the end of the game where they were asked to rate the game on different factors. The most relevant factor of the persuasion features was Emotional Engagement with the game.

Out of 120 students who played the game without the persuasion features, 52 responded to the survey questions. The sample was limited to the 30 students who played the game with persuasion features enabled. Out of the 30 students who played, only 13 took the survey. Responses have been normalized to percent of total on the Y-axis. Figure 21 shows the comparison between responses of the two populations.

![Figure 21. Impact of persuasion features.](image)

It should be noted that Y-axis of the graph is the percent of total population and not the count of students. Using percentage of total population aids in visualizing the
difference more easily. The graph indicates little difference in the ratings of the two populations. Therefore, it can be concluded that the persuasion features did not increase the player’s emotional involvement in the game.

Students who played the game with persuasion features were asked if they could identify themselves with the game family. Of the 13 total, 8 students said they could not identify themselves with the game family, whereas 5 students said they could. This again indicates that the persuasion features did not appear to produce the desired results.
Chapter 7  Conclusion and Future Work

7.1. Conclusion

This thesis presents a web-based, multiplayer, simulation game called GeoGame that teaches complex, real-world semantics of the green revolution to geography students. The game was developed using the ASP .NET MVC3 framework which, in conjunction with other supporting technologies, allows rapid and flexible game development. The ArcGIS server by ESRI was also shown to be compatible with the ASP .NET MVC3 web application to provide geo-processing capabilities.

To evaluate the game-based learning, an innovatively configurable assessment system was built. The assessment system successfully used the interceptor design pattern along with the web rule engine to create a configurable system.

To increase student engagement in the learning environment, the avatar and family-member names were added to the game. It was observed that these features did not produce the desired effect on students’ emotional engagement in the game.

The developed serious game was play tested with 186 students previously unfamiliar with the game. Student responses to in-game questions and the voluntary survey were analyzed to assess their attitude change towards the subject. It was observed that the game did give students a better understanding of how challenging farming in developing countries can be.
7.2. Future work

Based on the current architecture of the game, we propose a framework that generates a configurable game. This framework would be a three-layered framework with ASP .NET MVC as the first layer, a generic game engine as the second layer, and the rule engine as the third layer. The ASP .NET MVC layer provides a framework to generate a basic web application. The game engine provides capabilities like graphic generation, artificial intelligence, networking and memory management. The third layer would be the configurable layer that can be implemented using GeoGame’s assessment system architecture. This layer contains a rule engine allowing a user to enter the game rules. Using these game rules, the framework will generate a configurable game, meaning, the game can be easily changed by entering new game rules.

The current implementation of the game and data analysis also have areas in which additional work is suggested. Adding more features, which increase game dimensions, can facilitate students gaining a better understanding the subject. One useful feature could be adding environmental factors to the game. For example, if a player uses fertilizer, he/she may get a good yield initially, but frequent use of fertilizers will reduce the soil productivity. Likewise, adding features that use the geo-processing capabilities of the ArcGIS server can be beneficial. For example, if a player buys parcels of farmland which are separated from each other a significant distance, then his/her work capacity is reduced. Adding and evaluating more persuasion features can improve student engagement in the game. Adding a level-up option could be very constructive since that may motivate players to keep playing the game and try harder to succeed. For instance, if
a player reaches some level of success (it can be in terms of money or assets), he/she gets a level-up option, and a new feature (e.g., the use of a tractor, or a new crop, etc.) gets unlocked.

Additional data analysis with regards to the wealth of response data, can be administered using data-mining and text-mining techniques. The analyzed data can be used to identify patterns in strategies and random decisions. Novel visualizations such as indented tree, tree map, node-link tree etc. can be implemented to explore the analyzed data. These visualizations can help instructors in structuring their in-class discussions. Finally, applying these suggestions and further play testing them to measure their effectiveness would create for a more enjoyable, and perhaps, more educational game.
Bibliography


Appendix A Game Rules

The Turn

- Each turn in the game represents one growing season.
- A player is expected to go through a full cycle of planting and growing crops.
- At the end of each turn, the crop is automatically harvested.
- Further, during each turn, a fate card is drawn.

Land

- You must buy land when you begin the game.
- You get a specific amount of land for free, as specified by your family card at the beginning of the game.
- All other land costs the posted amount.

Wheat Varieties

- There are two types of wheat varieties to choose from.
  - Land races (LR) have strong yield stability.
  - The new high yield cultivars (HYC) of the Green Revolution have a high yield potential.
- Each acre of land requires one bushel of seed.
- You must decide what to plant each turn.

Fertilizer
• Each turn, you must decide if you will apply fertilizer.

• You can apply fertilizer at two levels, low or high.
  o High fertilizer is 80 lb. fertilizer per acre
  o Low fertilizer is 40 lb. to the acre.

• Fertilizer costs $1 per lb.

Weather

• Weather is determined at the end of the turn, on a scale of 1 to 5, with 5 being the best.

• This will be shown in the scoreboard once the turn is over.

• Plots with irrigation will have increased weather scores corresponding to the level of irrigation. (See “Irrigation”)

Yield

• Yield will depend on the type of seeds you use, the weather conditions, and the levels of fertilizer and irrigation inputs you apply to the crop.

• Your yield will be shown in your Market page as Grain.

• If you wish to sell your grain for money, you must manually sell your grain each turn if you choose to do so.

Labor Requirements

• Standard labor output
  o 1 adult (male or female) per 2 acres of unirrigated land
  o 1 adult per 1 acre of irrigated land
• An ox can be bought or sold for $1,000. An ox will reduce time for field labor by 50%, but must be driven by an adult male.

• This will effectively double the output of 1 adult male from the owner(s) of the ox.

• Labor output after purchasing an ox
  o 1 adult per 4 acres of unirrigated land
  o 1 adult per 2 acre of irrigated land

Children

• At least 3 children are required to collect firewood, look after goats and fetch water.

• If a family loses children and has less than 3 left, then 1 adult must stay at home.

• No more than 4 children under 10 years of age are allowed in each family.

• A child will become an adult after reaching 11 years of age.

Irrigation

• Each turn, you must decide whether you will irrigate.

• If you want to irrigate, you will need to purchase infrastructure. This costs $200, plus $0.50 per meter to the parcel you want to irrigate.

• When you purchase infrastructure to a parcel, all of your parcels which connect to it will be eligible for irrigation.

• Irrigation will raise the weather index by 1 for each level purchased. (See “Weather”)

• Any amount of irrigation will double the labor requirement for that parcel.
• Irrigation costs $2 per acre.

Consumption

• Each child needs 5 bushels of wheat/year.
• Each adult needs 9 bushels of wheat/year.
• If a family is in food deficit, people will die, starting with children.
• Food consumption for your family will be automatically deducted out of your yield at the end of each turn.

Transactions

• Families can buy things on the Market.
• They can buy from the Bank, or they can buy and sell things to each other.
• If you attempt to use more seed/fertilizer/water on a given plot than you have available, the supplies you need will be automatically bought from the market.

Fate Cards

The fate card introduces a random event into the game. The possibilities are:

• An new baby is born to one of the players
• A pest attack occurs and everyone loses half of their crop
• Oxen are available at half price for the following turn thanks to a relief organization
• High Yield seed is sold out for the following turn

The Timer

• Each turn is timed, and a timer is displayed at the top right of the screen.
• When the timer goes to zero, the turn is automatically advanced.
• If you are done early, you can press the Turn Finished button.

• If all players are finished before the timer ends, the turn is advanced.

Discussion

• This is a testing exercise.

• Discussion about the game, with fellow players and all other in the room, is highly encouraged.
Appendix B Assessment Questions Per Turn

The following items are administered at the beginning of each turn. Players must answer questions to proceed with the turn.

Turn 1

- Farming in developing countries is hard work, but farmers can still have some measure of success.
  a) Strongly agree
  b) Agree
  c) Neutral
  d) Disagree
  e) Strongly disagree

- Briefly describe what you think the biggest challenge you will face as a farmer in this game.

Turn 2

- In your opinion, which is the most important item to spend money on, irrigation, fertilizer or high yield seed (or some combination)? Briefly explain why.

- If you knew that there would be excellent weather and no pests for the coming season, how would that change your strategy?
  a) I would not change my plan at all.
b) I would spend less money on planting, fertilizing and irrigating.

c) I would spend more money on planting, fertilizing and irrigating.

d) I would spend the same amount of money, but change the relative amount of watering fertilizing and kind of seed I would use.

- What is your main priority for your money?
  a) Save some it in case there is a bad (low yield) year
  b) Save some for an ox or other large purchase.
  c) Spend all on planting, increasing yield.
  d) Spend almost of my money on planting, save a little for a large purchase.
  e) I don’t have any consistent strategy or priorities.

Turn 3

Items 3.1-3.6 are used depending on whether they used high-yield or land race seed in turn 2

- What are the advantages and disadvantages of using high-yield seed?
- What is needed in order for high-yield seed to succeed?
- Why did you purchase and plant high-yield seed? Was it a good choice?
- What are the advantages and disadvantages of using land-race seed?
- Why did you purchase and plant land-race seed? Was it a good choice?
- What is needed in order for land-race seed to succeed?
- If you knew that pest would wipe out half of your yield for the coming season, how would that change your strategy?
  a) I would not change my plan at all.

81
b) I would spend somewhat less money on planting, fertilizing and irrigating.

c) I would not plant at all.

d) I would spend more money on planting, fertilizing and irrigating.

e) I would spend the same amount of money, but change the relative amount of watering fertilizing and kind of seed I would use.

Turn 4

• What is your current strategy? (for example, are just trying to keep my family alive, are you spending all available money on planting, are you saving for to purchase a big item (land, ox etc)? )

• How well are you doing right now? Are things getting better or worse?

• If you knew that there would be bad weather (very dry) for the coming season, how would that change your strategy?

  a) I would not change my plan at all.
  
  b) I would spend less money on planting, fertilizing and irrigating.
  
  c) I would not plant at all.
  
  d) I would spend more money on planting, fertilizing and irrigating.
  
  e) I would spend the same amount of money, but change the relative amount of watering fertilizing and kind of seed I would use.

Turn 5

• What would you do with an extra $1000?

  a) Buy and plant as much fertilizer as possible with the money you have in your account
b) Irrigate planted land as much as possible with the money you have in your account

c) Buy and plant as much high yield seed as possible with the money you have in your account

d) Buy as much land the money you have in your account

e) Buy an ox

f) Save most of the money for bad years

• How well do you think you are doing compared to other players? Briefly explain why you think you are doing better, worse, or the same as others.

• High-yield seed is important for success.

  a) Strongly agree
  b) Agree
  c) Neutral
  d) Disagree
  e) Strongly disagree

Turn 6

• How would you define “success” in the game?

• How difficult is it to succeed in this game?

  a) Very easy
  b) Easy
  c) Not easy, not difficult
  d) Difficult
e) Very Difficult

- Have you communicated with other players about the game while playing online or during the day between turns? Was that helpful? Did it change your strategy?

Turn 7
- If you could do one thing differently in this game, what would it be?
- In your opinion, which kind of seed is better to plant, high-yield or land race? Briefly explain why.
- Did your definition or expectations of success for this game change during the course of the game? Briefly explain.
- Farming in developing countries is hard work, but farmers can still have some measure of success.
  a) Strongly agree
  b) Agree
  c) Neutral
  d) Disagree
  e) Strongly disagree
Appendix C Survey Questions

What is your major?

Are you: male/female (circle one)

Freshman  Sophomore  Junior  Senior (circle one)

Indicate Your familiarity with the following technologies:

Online maps (e.g. Google, Yahoo, Bing maps)

1  2  3  4  5

Never used  Use regularly

Advanced GIS software (e.g. ArcGIS, MapInfo)

1  2  3  4  5

Never used  Use regularly

Computer or video games including online games

1  2  3  4  5

Never used  Use regularly

You have participated in a computer game about rural farming in Punjab, India. Please
indicate to what degree you agree or disagree with the following statements:

Generally speaking, I could remain concentrated in the game

1 2 3 4 5
Disagree Agree

Comment/suggestions:

Workload in the game was equate

1 2 3 4 5
Disagree Agree

Comment/suggestions:

I received feedback on my progress in the game

1 2 3 4 5
Disagree Agree

Comment/suggestions:

The game interface and mechanics were easy to learn and use

1 2 3 4 5
Disagree Agree

The game supports social action between players
I felt emotionally involved in the game

Comment/suggestions: