Towards an Educational Computing Career Exploration Game

Dominic Kao
Alejandra J. Magana
Olaoluwa Oyedokun
Akash Ravi
kaod@purdue.edu
admagana@purdue.edu
ooyedoku@purdue.edu
ravi48@purdue.edu
Purdue University
West Lafayette, USA

ABSTRACT

Professionals with programming abilities are in high demand, but despite this urgent need, there is a lack of student interest. Researchers argue that in order to increase interest in computing, students require more opportunities for early familiarization, an understanding of how computing can make contributions to society, greater exposure to programming, online self-learning, internships, more visible role models and exemplars, and greater connections to the real world. This project aims to create a game that allows players to perform tasks from three computing jobs (web development, game development, and data science). Using the game as a testbed, the first study will develop an understanding of how different game design decisions affect the career game's effectiveness at engendering career-related and player-related outcomes. The second study will develop an understanding of how the career game as a whole influence career-related and player-related outcomes. The career game will be an informal learning environment that can be accessed by anyone with a desktop computer.

CCS CONCEPTS

• **Human-centered computing**;

KEYWORDS

Educational Games; Career Exploration; Game Design; Computing Education; Programming Education; STEM Education

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1 INTRODUCTION

STEM worker demand exists on every occupational level [104]. In the US, there are only 300,000 STEM graduates per year while the projected need is 1 million [64]. Professionals with programming ability specifically are in high demand [9, 87], with countries around the world adopting programming into national curricula [3, 9]. But despite urgent need for STEM workers [8], there is a lack of interest [15, 20, 28, 34, 102–104, 114]. In order to increase interest in computing, researchers have argued that students require more opportunities for early familiarization [105], an understanding of how computing can make contributions to society [4], greater exposure to programming, online self-learning, and internships [4], more visible role models and exemplars [4, 97, 111], and greater connections to the real world [25, 97]. In this paper, we propose a career game that can help mitigate stereotypes, allow for asynchronous access anytime and anywhere, promote visible role models, and enhance connections between problem solving and the real world.

A fundamental goal of educational games is to teach players relevant knowledge and skills [129]. Educational games have been widely explored with potential benefits to learning performance [68], interest [39, 92], motivation [35, 68, 140], problem solving [17], flexibility and adaptability [112], and positive emotional experiences [98, 118]. Yet while a significant number of researchers argue that student exposure to actual jobs and career experiences is crucial [4, 25, 37, 38, 55, 69, 105, 150], few educational games focus on career exploration. 21st-century careers are less linear, stable, and hierarchical [49] as a result of advances in technologies, globalization, and populations [59], making the need for individual career adaptability important [49]. Moreover, misconceptions about Science, Technology, Engineering, and Mathematics (STEM) work are common among students [37]. As such, researchers argue that career exposure increases the potential for employment that matches preferences and abilities [144], avoids mismatched expectations [76], enables upward mobility [69], and improves overall well-being [76]. This exposure has typically been through internships [108], practicums [69], clubs [31], hobbies [71, 94], and outreach [77]. Yet these activities are heavily based on self-selection [71] and availability of opportunities [69], and as a result, support only a limited number of students. Increasingly, researchers are instead developing technologies to bring workplace experiences to students.

We propose studies on whether educational games that re-enact occupation relevant tasks can be effective for promoting career exploration. The career game proposed in this paper revolves around an internship at a computing company with three departments: web development, game development, and data science. The goal of this game is to expose players to early career-relevant experiences that can influence individual career decisions, development, and well-being [76].

2 RELATED WORKS

2.1 Significance and Background

Career refers to the work-related roles in a person's life [7, 134], and more broadly also encompasses non-work roles, e.g., student [134, 135]. Career exploration, or "purposive behavior and cognitions that afford access to information about occupations, jobs, organizations that were not previously in the stimulus field" [132], is considered increasingly important to keep pace with the rapidly changing nature of work [26, 69, 70, 138]. Career research is grounded in theories that focus on the variables that influence interests, choices, and success [84]. This includes theories that encompass the multiple roles a person has in their lifespan [82, 134–136]. Of the instruments that measure career-related outcomes [57, 65, 66, 70, 85, 121, 122, 132], career exploration is the most widely used [41, 82, 83, 132, 134]. Career exploration facilitates positive outcomes such as improved career planning, personally meaningful work, and ability to cope with change [14, 121, 152, 153], while also positively influencing decision-making [13, 23, 24, 85, 86] and employability [43, 109]. In this work, we propose to use validated measures of career exploration and related constructs (adaptability [121, 122], self-efficacy [85], and interests [85]).

Career-related scaffolds in schools are rarely helpful [145], unengaging [5, 90, 131, 143], ill-equipped [2], and are unable to keep pace with the rate of change [61]. Nevertheless, existing games with career exploration are sparse [16]. In [66], a game was developed to assess personality types through a series of mini-games, the outcome of which was used to find the most appropriate jobs for each student. Researchers found positive short-term effects on career exploration related measures [66]. Our own preliminary work using university students currently undecided on their major has found that presenting students with historical employment data on different occupations positively influences career exploration [72]. However, research combining an engaging virtual experience with career exploration is still missing. This paper addresses this need by proposing a game specifically for career exploration.

2.2 Video Games and Education

Forecasts show that the global gaming industry will generate 196 billion dollars in 2022 [148]. While there exist longstanding debates in the field [6, 40, 51, 54, 58, 81, 139], proponents of games posit that video games encourage extensive out-of-game learning [53]. Educational games (also referred to as serious games [100], edutainment [19], and game-based learning [30]) can be highly motivational [35, 39, 62, 68, 75, 92, 128, 140], effective as learning tools [52, 58, 101, 106, 133], and provide safe environments to experiment [58]. Educational games can foster the development of 21st-century skills, e.g., critical thinking, self-discipline, and problem solving [73, 110, 113, 117, 127]. Educational games have been leveraged widely, e.g., STEM, arts, and medicine.

One of the biggest shifts in learning theories has been one from learning as a knowledge acquisition metaphor [124] towards learning as instead being fundamentally contextually situated [10, 60, 79, 80, 115, 142, 146, 151]. One advantage of an educational video game is that it can enable a "practice perspective" to learning. In a practice perspective, the focus of learning is on participation in authentic experiences, where learning environments: (a) are personally meaningful to the learner, (b) relate to the real world, and (c) provide an opportunity to think in the modes of a particular discipline [125]. Well-designed educational games can create highly engaging and authentic experiences [130].

2.3 Video Games and Career Exploration

Studies utilizing games focused on promoting interest in STEM fields include simulation games, role-playing games, and arcade-like games [11, 32, 45–47, 63, 96, 126, 137]. The *eCity* game enabled career exploration by exposing students to non-trivial problems in city planning that challenged them to think as engineers and apply skills from STEM subjects [32]. A positive correlation was observed between the participants' enjoyment and their willingness to pursue an engineering career. In another game, students navigated the 3D game using a vehicle and were quizzed on job roles and biographies of those from diverse career paths along the way [47]. A significant difference was observed in the interest levels before and after playing the game, suggesting that the game had positively influenced interest in careers in science. Factors such as student age, gender, and background can affect the extent to which such games are successful [32, 47, 96]. Although such games have been reported to be interesting and motivating [11, 46, 137], most of these interventions have measured outcomes such as interest and motivation and not specifically career exploration outcomes–one of the core goals of our current project.

3 METHODOLOGY

3.1 Game Design

The goal of this project is three-fold: (1) to build a career game, (2) understanding the impact of individual game design decisions on career exploration, (3) to study the game's effects as a whole on players' career exploration and game experience outcomes. For game design decisions, we will run two multivariate studies, with each study varying a number of game design choices. The knowledge gathered from this study will equip educational game designers to make more informed decisions when career exploration is a goal of the game. In addition, we will perform a study with Purdue University students who are undecided on their major to study how being exposed to the career game over the course of one semester can influence career decisions. This assesses the longitudinal effects of the career game. We will address the following research questions:
RQ1. How do different game design decisions in the career game influence career exploration and game experience outcomes?
RQ2. How does the career game affect players' career exploration and game experience outcomes?

The career game has three playable occupations which involve performing occupation-relevant tasks: web developer (selected because web development combines technical [29, 107] and creative [36] competencies), game developer (selected because game development fosters positive attitudes towards computing [27, 33]), and data scientist (selected because data science is increasingly crucial in today's society [44, 78]). The Occupational Information Network (O*NET), an initiative sponsored by the U.S. Department of Labor/Employment and Training Administration (USDOL/ETA) lists these three domains as bright outlook occupations. O*NET forecasts that in the U.S. game designers and web developers are projected to have a growth percentage of 10 to 15% and an estimated 17,900 job openings between 2020-2030, while data scientists are estimated to have a projected growth rate of 15% or higher and an estimated 7,100 job openings between 2020-2030 [42]. Therefore, these occupations are categorized as having the potential to grow rapidly in the near future and generate significant employment opportunities.

To design the game, we used several references for building the gameplay [88, 116], engagement loop [91], and budgeting development work [48]. The player starts as an intern at a virtual computing company at the beginning of the game and can interact with different employees who will provide one-line responses. These responses will be career text 60% of the time (e.g., "I just found out there are over 150,000 web developers in the U.S.!") and miscellaneous text 40% of the time. The character movement is controlled using the WASD keys and mouse-look, with spacebar key for interaction. The game is designed to be played on a desktop device through the browser using WebGL. There is no lose condition for the game.

At the start of each game day, which lasts 30 minutes, the player begins at the reception. The player is asked to find the manager's office, where they can switch which department to work in, and where they return to at the end of each game day. See Figure 1 in the online Appendix[1] for an overview and a typical game day. When the player sits down at a hot desk (a designated computer station), they can begin a module. Each module consists of a learning section where players will complete a guided walkthrough of a specific topic and is re-playable. Each module ends with a test that includes some combination of multiple-choice questions and coding tasks. Test questions are randomly drawn from a pool of questions for the topic. Each occupation type has a pathway that progresses from basic to advanced. See Table 1 for the primary learning objectives of each occupation.

In the staff social area, a laptop can be accessed that functions as a job board. The job board displays computing career pathways, salaries, duties, locations, and real-world companies. The job board will also be a special module that the manager will periodically ask the player to complete. These modules are designed to test the player's knowledge about computing careers. Data for the job board will be estimates taken from a variety of publicly available data sources on the U.S. job market. Feedback on player performance is provided at the end of each day by the manager, every seven days through a weekly report card, and an internship report at the end of the game. The performance takes into account test scores, tasks completed without help, time spent on different workplace activities, job board viewings, and the number of co-worker interactions. A total grade is assigned through the sum performance of these measures.

[1]A full list of figures and mock-ups pertaining to the game design can be found in the online Appendix: https://osf.io/4z3a6/. The online Appendix includes mock-ups of the office environment, the core engagement loop, the interactive coding screen, job board, report card, and an alignment between game features and our theoretical framework. Note that game images in the storyboard and figures are mock-ups only and do not represent the diversity in characters (e.g., race/ethnicity) that will be present in the actual game.

Table 1: Main Topics and Learning Objectives.

Occupation	Topics	Core Learning Objectives
Data Scientist	Python; Pandas; Data Visualization; Statistics; Hypothesis Testing; Machine Learning	Fundamentals of Python, Pandas, Data Visualization, Statistical Analysis, Supervised and Unsupervised Machine Learning Algorithms
Web Developer	HTML; CSS; JavaScript	Fundamentals of HTML, JavaScript, and CSS
Game Developer	JavaScript; Phaser	Fundamentals of Game Programming, JavaScript, and Phaser

3.2 Theoretical Framework for the Research Design

The theoretical framework for this study is based on Social Cognitive Career Theory (SCCT) [83], which explains career outcomes primarily through one's self-efficacy, outcome expectations, and personal goals. We draw upon Career Self-Management Theory (CSM) [82], which is an extension of SCCT and incorporates a model of adaptive career behaviors throughout the lifespan of an individual. We leverage Stumpf's Career Exploration [132], which models the where, how, how much, and what, of career exploration. All of these theories are highly pervasive in career exploration research [70]. For understanding player experience, we use the Player Experience of Need Satisfaction (PENS) framework [119]. In our game design, we leverage James Gee's principles of good learning in video games [50].

3.3 Research Design

The research plan consists of two phases. In phase one, we will develop the career game using an iterative approach to facilitate early throw-away prototypes [67]. In phase two, we will conduct two studies. The first study (Study A) and the second study (Study B) will focus on the effects of design decisions and playing in the career game respectively.

3.3.1 Phase 1: Game Development. Phase 1 will focus on the development of the career game. Game iterations will be evaluated using Rapid Iterative Testing and Evaluation (RITE) [99]. RITE participants will consist of university students and faculty (i.e., for both player and educator input) recruited locally. These iterations will focus on usability, learnability, and enjoyment. Modules will be played and vetted by domain experts. Because careers rapidly change over time [26, 69, 70, 138], one goal of the career game is extensibility. Thus, career paths, modules, and NPC dialogue will be represented as JSON to facilitate additions.

3.3.2 Phase 2A: Experimentation: Game Design Choices in the Career Game.

RQ1. *How do different game design decisions in the career game influence career exploration and game experience outcomes?*

Intervention: This study examines game design decisions' influence on career exploration and game experience outcomes. The goal is to project the following six game design mechanics:

(1) Job-Info: The presence (vs. absence) of real-world job and career information integrated into the core gameplay. This is operationalized as an in-game job board. Real-world job information can help foster more accurate outcome expectations and allow for increased career exploration.
(2) Multiple-Jobs: The presence (vs. absence) of the three job types (Web Development, Data Science, Game Development). In the absence condition, one of the three job types is randomly selected at the start of the game. The player will only have access to tasks in the randomly selected job type. The game design will be adapted. Having multiple job choices in the game can enhance autonomy and lead to increased exploration of different occupations.
(3) Flat-Difficulty: The presence (vs. absence) of tasks that have a flat difficulty curve (are all easy). Flow theory [149] posits that activities should *provide a continuously optimal (intermediate) level of difficulty for the learner* [93]. However, recent work has shown that easy difficulty levels in educational games can be most motivating [89]. Making the tasks easy can increase SCCT's self-efficacy, thereby having a positive cascade effect on SCCT and CSM variables.
(4) Avatar-Customization: The presence (vs. absence) of avatar customization. One version of the game's avatar creator will allow the player to customize their avatar. In the absence condition, following a procedure from prior work [12], participants will watch a video of the customization of their avatar. Avatar customization promotes avatar identification [12], which enhances game experience outcomes and motivated behavior.
(5) Role-Model-Salient: The presence (vs. absence) of a salient role model. The presence condition will contain a mentor role model that is matched visually to the sex and race/ethnicity of the player, and whose success within the company is evident in the role model's dialogue with the player. In the absence condition, the mentor will have a randomized sex and race/ethnicity, and will not demonstrate clear success.
(6) Environmental-Stereotypes: The presence (vs. absence) of environmental stereotypes. The presence condition will contain a stereotypical male office computing environment, which can potentially significantly hamper women's sense of belonging, interest, and anticipated success in computing [21]. Both the stereotypical and non-stereotypical environments will be validated through a pre-test prior to being deployed in the study, similarly to [21].

To study the factors above, we will run two multivariate $2 \times 2 \times 2$ experiments. The first experiment will vary the three job-related variables (Job-Info, Multiple-Jobs, Flat-Difficulty). The second experiment will vary the three virtual environment-related variables (Avatar-Customization, Role-Model-Salient, Environmental-Stereotypes). In addition, we seek to understand the predictive capacity of different variables on career exploration outcomes (described in the Analysis section). This single-session study aims to understand how different game design factors influence career exploration and game experience outcomes the very first time a player sits down to play the game. This initial play session is understood as crucial in whether a player decides to continue playing [22].

Quantitative and Qualitative Measures: See Table 2 for measurement instruments.

Table 2: Measurement instruments in Study A.

Conceptual Group	Instruments	Time
Career Exploration Outcomes	Career Exploration Survey [132]; Career Adapt-Abilities Scale [122]; Career Exploration and Decision Self-Efficacy Scale [85]	Pre/Post
Game Experience Outcomes	Player Experience of Need Satisfaction [119]; Player Experience Inventory [1]; Intrinsic Motivation Inventory [95]; System Usability Scale [18]	Post
Interest in Computing Careers	Computing Career Interests (adapted from [74] and [57])	Pre/Post
Computing Self-Efficacy	Programming Self-Beliefs Scale [123]; Computer Science Attitude Survey [147]	Pre/Post
Avatar Identification	Player Identification Scale [141]	Post
Performance, Engagement, and Persistence (game analytics)	Player Data (progress, in-game scores, time played, successes and failures)	During

Nearly all of these survey instruments are robustly validated. For adapted surveys or surveys yet to be fully validated, reliability measures (e.g., Cronbach's alpha) will be calculated. Domain experts will additionally assess individual questions to ensure their applicability to the study before being included.

Participants: Young adults aged 18-25 will be recruited for this study from Purdue University, West Lafayette. Approximately half of all empirical career exploration research focuses on young adults [70], and also constitutes the focus of this project.

Procedure: Players are randomly assigned to conditions. Players will play the game for a minimum of 20 minutes, after which they can exit at any time. Data collection will occur as depicted in Table 2.

Analysis: The two studies each have three independent variables with two levels, totaling 8 unique treatment combinations. We will study both main effects (i.e., A, B, C) and interaction effects (i.e., AB, AC, BC, ABC). In addition to studying each experiment's manipulated variables, we will use hierarchical linear regression to determine the predictive capacity of different variables on career exploration outcomes. These variables (collected as post-test variables) will include: interest in the three job types, self-efficacy in the game (i.e., competence, mastery), player identification with the avatar, and the relatedness with in-game characters. Data will be collected through surveys and game analytics. Survey and analytics data will be compared between conditions and as predicted variables in regressions.

3.3.3 Phase 2B: Experimentation: Effects of the Career Game on Exploratory Studies Students.

RQ2. *How does the career game affect players' career exploration and game experience outcomes?*

Intervention: This study will examine the effects of the career game over a 1 year period. The version of the career game used in Study B will leverage the most advantageous design decisions for career exploration outcomes from Study A. At the start of the study, each student will be randomly assigned to one of three conditions. In the *Full-Game* condition, students will have access to the career game. In the *Programming-Problems* condition, students will have access to only the programming problems found in the career game grouped by the original job names (Web Development problems, Game Development problems, Data Science problems). The *Programming-Problems* condition will contain only programming problems in a web interface, with problems sorted by difficulty. This condition is essentially the bare-bones technical tasks isolated from the career game. In the *None* condition, students will not be exposed to any material (control condition).

Quantitative and Qualitative Measures: Data will be collected from four surveys, a pre/post during the semester, one follow-up at eight months, and one follow-up at twelve months. Additionally, we will utilize log data and interviews. Students in the *Full-Game* and *Programming-Problems* conditions will be interviewed in the post-test for a 30-minute follow-up interview. The interviews will be semi-structured, investigating:

- Students' perspectives on the computing activity's effectiveness for career exploration
- Students' career exploration behaviors inside and outside of the game
- Aspects of the computing activity students found effective/ineffective for engendering career exploration
- Students' motivations for accessing the computing activity and whether it is worthwhile

The triangulation of different data sources here will improve the validity of our findings. The follow-up surveys will also help to develop an understanding of the actual decisions (the decision of which major to pursue) that students make after the intervention. See Table 3 for measurement instruments.

Table 3: Measurement instruments in Study B.

Conceptual Group	Instruments	Time
Career Exploration Outcomes	Career Exploration Survey [132]; Career Adapt-Abilities Scale [122]; Career Exploration and Decision Self-Efficacy Scale [85]	Pre/Post/F1/F2
Game Experience Outcomes	Player Experience of Need Satisfaction [119]; Player Experience Inventory [1]; Intrinsic Motivation Inventory [95]; System Usability Scale [18]	Post
Interest in Computing Careers	Computing Career Interests (adapted from [74] and [57])	Pre/Post/F1/F2
Computing Self-Efficacy	Programming Self-Beliefs Scale [123]; Computer Science Attitude Survey [147]	Pre/Post/F1/F2
Avatar Identification	Player Identification Scale [141]	Post
Performance, Engagement, and Persistence (game analytics)	Player Data (progress, in-game scores, time played, successes and failures)	During
Interview	Semi-Structured Interview	Post
Career Decision	Choice of University Major (if any)	Post/F1/F2

F1–8 month follow-up; F2–12 month follow-up

Participants: Participants will be recruited from Purdue University's Exploratory Studies program. This program gives students across all of Purdue University who are undecided on their university major the opportunity to take up to four semesters to decide. This group of students falls in the young adult age range, and because they are deciding on a university major, the career game will be of high relevance to them. We will seek to recruit 200 participants.

Procedure: Student accounts for accessing the study conditions will be provided, which will log activity. Students will be asked to access the game, or the programming problems, at least once per week, for a minimum of 20 minutes (13 weeks over the semester × 20 minutes = minimum of 260 minutes). Accessing the condition for a period of time longer than 20 minutes in a week is optional. Students will be sent automatic reminder e-mails when we do not log sufficient access time, and (non-)adherence to these guidelines will be recorded. Data collection will occur as depicted in Table 3.

Analysis: We will primarily be studying differences across the three conditions using MANOVA, ANOVA, and post-hoc testing. We will also be characterizing how students perceived the computing activities in the *Full-Game* and *Programming-Problems* conditions through the interview data. Interviews will be analyzed using grounded theory [56, 120] using a two-round coding method outlined by Saldana, which involves first identifying and describing codes, then describing common themes and patterns [120]. Similar to Study A, we will calculate reliability measures and leverage domain experts to ensure the applicability of survey instruments that are adapted or not yet fully validated.

4 CONCLUSION

The goal of this project is to develop an educational game that increases exposure to computing careers. Single-session user studies will help us determine game design decisions' effectiveness at engendering career-related and player-related outcomes. A longitudinal study with exploratory studies students will capture extensive data which will help develop an understanding of how playing such a career game affects career exploration outcomes. The triangulation of multiple data sources will improve validity. Primary indicators for assessing the success of the career game will be motivated behavior, in-game progress, career exploration outcomes, and game experience outcomes.

Educators and researchers will be able to leverage our work to systematically study this domain. Through the outcomes of this project, this work is expected to stimulate future research. By fully exploring the potential for educational games and career exploration, additional bridges between education and the workforce can be created, making career exploration more widely available.

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