

Critical Success Factors in Creating an Online Introduction to a Programming Course

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Abstract

Covid-19 has brought about monumental changes in the world including the field of Computer Science Education (CSEd). The recent trend in increasing technological access affords institutions new means by which to deliver content - online distance learning (ODL). These two events have spurred an increase in demand for changes in the typical classroom environment. There is a global demand for new learning environments and cyber-classrooms. This means that new methods, technologies, and ways of teaching must be created or used in order to increase the probability of success in such environments. This research topic is specific to an introductory programming course that will be presented online for the first time at the University of Cape Town. It is thus the duty of this paper to come up with critical success factors (CSFs) that may enhance a student's likelihood of successfully completing this course. When determining success, we are using pass-rate as our core-success factor, as this is what we are aiming to maintain in our transition to an online learning medium.

This literature review aims to classify and evaluate the academic literature that is believed to be relevant and useful for the purposes of gaining insight into this honours research project. Lots of literature has been read - however only the most relevant and reliable sources with contextually suitable topics for this research title will appear here.

It was not possible to identify CSFs which guarantee certain success in our current context at UCT but this paper does highlight various CSFs which have proven to increase the probability of course completion in the context of an online learning environment.

Keywords

CSF (Critical Success Factor); CS1 (Computer Science); ODL (Online Distance Learning); CSEd (Computer Science Education); SRL

(Self-Regulated Learning); LMS (Learning Management System); E-Learning (Electronic); Distance Education; Gamified Learning (GL).

Introduction

Technological advancements have triggered inventions in the teaching and learning process. The introduction of a multitude of online courses offers students many opportunities to enroll in CS courses of their choice, while transcending geographical barriers. However, online learning puts an enormous responsibility for learning on the learners and lacks direct faculty-student and peer-peer interactions in the traditional sense. These essential collaborative relationships need to be renegotiated for learning to be successful. The instructor's role must also be redefined so as to optimise support and to scaffold collaborative learning in the online environment.

This paper aims to come up with CSFs that could be adopted by tertiary institutions to maximise their chances of improving their online learning programmes' success rates. The focus of this research is on an online introductory programming course, however some of these success factors are broad and can be used in other settings too. This paper ignores success factors that have not proven to be critical as well as other factors that have not been shown to enhance the probability of increasing the success rates of the course, while specifically referring to an asynchronous learning environment, one similar to the one here at UCT.

Motivation

It has been found that drop-out rates in online learning environments are higher than regular learning environments. This paper aims to reverse/lessen this trend and to enhance the students' learning environment in such a way that will enable and empower them to successfully complete their online courses.

In bold are the critical success factors (CSFs) that can be attributed to successful outcomes for an online introductory programming course.

Presentation

This review will run through the key points from various different papers that relate to the field of computer science education. This paper shall also critically analyse the pros and cons of each paper by providing short-comings and highlighting important contributions specific to this research topic. Common parallels that were identified in most papers included the success factors that are related to our studies of Computer Science. Common shortcomings were that most of the studies were not conducted within the South African context.

Several studies have found that drop-out rates of online courses are higher than face-to-face courses [1,2,3]. To mitigate these high rates of unsuccessful course completion, Campbell et al. [1] aims to find methods and factors that can enable success in an online environment. It found an important factor for online success to be **self-efficacy** and another study by Cho and Shen [4] showed that having a **strong teaching presence**, as well as encouraging students to **set attainable goals**, would encourage self-efficacy success. Campbell et al. [1] found that test anxiety was a negative factor in terms of exam success for online students. They found that online students must **complete exercises analogous to exam questions** to avoid this hindrance. Study Bergin et al. [5] found that **self-regulated learning (SRL)** such as stronger metacognitive skills and better management of resources were associated with higher grades on introductory programming performance.

The positive aspects of Campbell et al. [1] were that it was written relatively recently (2016) and it was specific to a CS1 course (an American equivalent to an introductory course in programming). It also aimed to come up with success factors for such a course. The shortcoming in this paper was that the study was specific to their university setting. The course had a flipped classroom as well as an online one. It was a comparative study based on only their two types of classroom, so the comparison was general and not very broad.

Online courses are defined as having at least 80% of the course content delivered online [7]. ODL includes benefits such as 24-hour access to information, up-to-date content materials, self-paced learning, customised courses, and cost effectiveness [6].

According to Cheawjindakarn et al. [6] the CSFs can be grouped into four core factor types, namely: institutional management, learning environment, instructional design and services support. Each factor type consists of elements which this study will explore.

Institutional management's (IM's) first element is **market research** - the analysis on target group requirements with the awareness of ODL. IM's second element is **program framework**. This is to determine the framework and scope of the program, as related to definitions used in operation, while accommodating changes in organisational strategies and directing the implementation of the online course in ways that best support the students progress. IM's third element is the **operational plan**. This is the management style of the institution, including the integration of online learning into the curriculum as a whole, as well as the overarching goal of enhancing academic activities. IM's last element is **cost effectiveness**. This includes managing the budget and making the budget significant enough to effectively carry out the course in an online manner.

Learning environment's (LE's) first element is the **learning management system (LMS)** such as UCT's own system which is known as Vula. The LMS is an environment that provides an instructor with a set of tools and a framework that allows the simple and efficient creation and teaching of online course content. LE's second element is **technical infrastructure**. This means that universities must have supportive, quality technology for online courses. To facilitate the students, the simplest and easiest access to learning must be supplied. The necessary tools must be provided to make the delivery of ODL as successful as possible. This factor is associated with hardware and software technologies such as high-speed internet access, bandwidth, system availability, and network security. LE's third element is **interactive learning** which includes some form of interaction and collaboration among students as well as between learners and instructors. Learner-learner interaction is a CSF when course satisfaction is measured [8]. LE's last element is **access and navigation**. This refers to interface design which must facilitate communication and learning activities of the online course. This links back to LE's first element which is the LMS. Navigation is important to allow students to quickly find programs and content and the system must be user friendly.

Instructional design's (ID's) first element is the **clarification of objectives**. These are clear learning goals which must be set at the beginning of

the program. Students should easily be able to access the course syllabus and be able to have a clearly defined path, with decent structure to aid with their learning needs. ID's second element is **content quality**. Good content quality depends on well-designed and carefully selected course material which will facilitate a meaningful educational experience. ID's third element is **learning strategies**. Courses should support the "student-centered" principle by ensuring that course instructors play a central role in the teaching and learning experience, while still maintaining that the student has user control. Encouraging instructors to teach and students to study, is essential, and can be done effectively by methods which integrate technology into appropriate learning strategies [9]. ID's fourth element is the **psychology of learning**. Students must be motivated and committed by themselves or by the instructors. ID's last element is **learning assessment**. As always, assessment methods must be valid, reliable, flexible, and fair.

Services support's (SS's) first element is **training**. This is to improve the ability of people to adapt to the technologies and to the different interactivity learning levels. Enhancing students' computer literacy and online learning application skills can make them feel more like using the online method. SS's second element is **communication tools**. These tools vary widely and are dependent on various circumstances, such as strategic goals and objectives as well as the budget. Appropriate online communication tools are essential for academic success. SS's last element is having a **help desk**. Establishing a help desk is one of the best ways to assist students. Access to human resources is also important, such as expert users, technical assistants, and advisors.

Cheawjindakarn et al. [6] has the downside of being slightly outdated. The literature reviewed was taken from 2000-2012. A positive factor was that a decent number of papers were analysed (19 in total). The paper was therefore very broad and covered ODL as a whole. However, it was not specific to a computer science environment.

Volery and Lord [10] identified that there are 6 CSFs for online education. The first factor is **ease of access and navigation**. This comprises the variables which relate to the ease with which students can access the site and the usability of the software in general. Flexibility in terms of times (24-hour access) was also notable. The second factor is **interface**. This relates to the visual structure and design of the course. An important aspect was having an appealing and well-structured web page design. The third factor was **interaction**.

This relates to the interactive abilities of an online course between instructors and students. A true virtual classroom was an important aspect of the interaction factor. There was a strong relationship between instructor characteristics and teaching effectiveness. The fourth factor was **attitudes towards students**. The instructor's personal approach and teaching manner are important and the instructor must show empathy towards students. Factor five was **instructor technical competence**. This relates to the instructor's ability to use and promote the internet technology (LMS) effectively. The final factor was **classroom interaction**. The instructor's ability to encourage students to interact and participate in class is significant.

Volery and Lord [10] used WebCT (a Web publishing software to develop online courses) as its basis for finding data, which may be different to a pure university setting. The study also used a small subset of persons (47) enrolled in Global Business for its anonymous questionnaire, which may be too few for a good finding. Student grades were not available at the time of the study, so that was another limiting factor in its efficacy.

Quille and Bergin [11] is a literature review based on over a decade worth of papers from 2005-2018. The paper sets out to describe the evolution of a prediction model named PreSS. This model was created to predict student success rates in introductory first year Computer Science (CS) courses with an accuracy of 71%. The research showed that two CSFs for struggling students are **running a Scratch course alongside CS1** as well as **promoting a growth mindset**.

Quille and Bergin [11] benefits from it being longitudinal in its time frame and being recent (published 2019). It is also very specific to the CS context for an introductory course (CS1). The paper focuses on the PreSS model which could not be found (however it could potentially be useful to UCT if located as it was apparently available in an online toolbox which was ready to use [PreSS#]). This was an incredibly comprehensive study and one which sets the standard for CSEd. It was multi-institutional and its findings were quite novel, being the only study of its kind so far according to the authors.

Korkut et al. [12] outlines how to create successful videos in a Massive Open Online Course (MOOC) environment, however the techniques can still be translated into our setting. The CSFs outlined in this paper are on methods to increase engagement. The methods/conclusions included the following tips which allowed for better engagement with the audience: **shorter videos, videos with talking**

heads of professors, free hand sketching while explaining concepts, quick speaking and enthusiasm, and tutorial (procedural videos) videos. Video production and styles can affect student engagement [13]. **Proper investment in pre-production** is noted as a CSF i.e. editing, polishing, attention-grabbing etc. A research article by Hibbert [14] describes factors that increase views and engagement: **videos with direct connection to course assignment, videos with professors' humour and wit and sophisticated, high quality professional looking videos with visuals and artefacts. Gamification** was proven to improve views and engagement too.

Korkut et al. [12] was created for MOOC, which is different from a university class setting. The other issue is that it based its success factor on popularity, which may not be easily translated to our context. Improving video content would be beneficial in any circumstances where videos are implemented so it is still useful for instructors to consider these pointers when creating their content.

Alqahtani and Rajkhan [15] is a recent paper that was created specifically with Covid-19 as the basis for finding its impact on CSFs for E-learning during this crisis. The paper concluded with the following CSFs being the most important factors to a successful E-Learning environment: **knowledge management, support from management, student characteristics, and a high level of information technology from instructors.** Knowledge management focuses on the management knowledge within the educational institution for faculty members and administration. Support focuses on supporting both the instructors and the students to enhance their experiences. Student characteristics focuses on the students environment while learning. Information technology focuses on the information technology system which delivers learning materials and objectives.

Alqahtani and Rajkhan [15] was multi-institutional and benefited from being current (it was published in 2020). It explains that previous papers on CSFs were done during "typical times" which differ from the current crisis that we find ourselves in during this global pandemic. It is truly an abnormal time and the fact that this paper addresses the challenges during the pandemic is key. The paper acknowledges the lack of materials, resources and literature around the effects of the pandemic. The tools used in the paper are also sensitive to situation and perspective and therefore the paper's findings may not be accurately replicated in different areas or circumstances.

Discussion

There was a large variety in the CSFs identified in many differing papers. This makes sense because the papers span a wide variety of institutions, countries, learning methods, levels of learning and types of learning. This literature review has tried to ensure that every paper contributes something useful which can be used for further exploration and extrapolation in our current context in a South African tertiary institution. We want to be able to make effective recommendations based on proven methodologies, pedagogies and processes to ensure the successful implementation of an online introductory course to programming, within a unique learning environment.

Critical Comparison

Every paper had limiting aspects as well as some unique perspectives on different topics. A wide variety of papers was explored and ones that could be used and that were congruent with the research topic were exploited in this literature review. These findings will be used for furthering this research project. Critique of each paper was given after the CSFs were identified in the presentation section of this literature review.

Chosen CSF To Evaluate Further: Gamification

We have chosen to explore the gamification aspect of education so as to utilise its possible benefit in an online introductory course to programming.

Gamification is one of the educational approaches and techniques that increases motivation and engagement of learners [16]. We have chosen it as we believe it is currently not being exploited enough and it has the potential to have good outcomes, based on the literature around it.

Another reason for choosing gamification is that E-learning is suitable for easy and effective integration of gamification [16].

Gamification is an effective approach to make positive change in students' behavior and attitude towards learning, to improve their motivation and engagement [16].

Sousa-Vieira et al. [17] found that their results consistently showed that a positive correlation is always present between individuals in the Gamified

Learning (GL) group and better academic achievement. These students attained better grades and had a better probability of success in the final exams, were much less prone to quit the course, and provided more frequent contributions and information to the forums. They were usually high quality and better critical thinkers.

The studies by Kiryakova et al. [16] and Sousa-Vieira et al. [17] demonstrate the efficacy of gamified learning in an educational environment.

Conclusions

Due to the wide variety of CSFs identified, it is not possible to decide on the single most important or critical factor for success in an online course. It is not even possible to develop a ranking for the importance of factors. However, it is possible to create a comprehensive list of multiple factors that will increase the probability of a successful course outcome. This paper has identified (in bold) and described the contributing factors and their definitions.

Further research must be done which would be relevant and contextually accurate. The global pandemic within the South African context is unique in many ways. However, CS1 specific topics certainly lend themselves better to online learning than many other mediums of study at tertiary level. While many factors are certainly unique in terms of how we implement these findings, there is enough evidence from these studies to use as a foundation for further research - in terms of the context of the Covid-19 pandemic scenario. Other new fields to explore which a current lack of literature would be furthering research into CS1 specific topics, grouping of CSFs into different categories and furthering improvements for CSEd specifically for ODL.

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