



Factors that Influence the Success of the CS2 for Students Who Failed CS1 Programming Course

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Abstract

CS1 and CS2 are two fundamental programming courses in Computer Science (CS) education. Mostly, CS1 focuses on basic algorithm design and programming concepts while CS2 introduces more advanced data abstractions and data structures. There is a general consensus that for successful learning of CS2 courses, students must learn and pass CS1 at least with a satisfactory level before learning CS2. To date, there are limited empirical studies that have examined the factors that can influence students who initially failed CS1 to pass CS2. The aim of this study was twofold; first to determine if there exist a substantial number of students who failed CS1 but managed to successfully pass CS2; and second, to examine the factors that influenced the success of CS2. The subjects of the study were 736 undergraduate students who were studying a CS2 course at the College of Informatics and Virtual Education (CIVE) of the University of Dodoma in Tanzania. The study employed a mixed research approach. Data were collected by using documentary review (students' examination reports), questionnaires and interview methods. Data from 2013-2018 examination reports and questionnaire were analyzed by using descriptive statistics while data from students' interviews was analyzed by using the content analysis method. Results show that within a period of five consecutive years from 2013-2018, 20.52% of the students who failed CS1 at CIVE managed to pass CS2. The key factors that were identified to influence the students' success of CS2 despite their failure in CS1 were the tendency of the students who failed CS1 to build new confidence after the initial failure, the change of student living and learning styles, reviewing programming thresholds, and avoiding rote learning. To help students understand CS1 and CS2, the study recommends instructors who teach programming to motivate students and use teaching strategies that encourage self-efficacy attitudes among the students.

Keywords: CS1; CS2; Programming; Computer Science; Failure Rate in CS2

Abbreviations

CS: Computer Science; CIVE: College of Informatics and Virtual Education, Association for Computing Machinery; OOP: Object-oriented Programming; UDOM: The University of Dodoma; ICT: Information and Communication Technology; SPSS: Statistical Package for Social Sciences

Introduction

Programming is defined as the act of writing computer programs [1]. It is the science of instructing the computer to solve

real-life problems in a more efficient way. In order to master programming skills, a novice has to learn several programming courses. For most universities, the first programming course that students learn during the first year is introductory programming (commonly known as CS1. The next course is called data structure and algorithm, which is also known as CS2. The third course is usually Object-oriented Programming (OOP). The Association for Computing Machinery (ACM) recognizes CS1 and CS2 as two among the eight courses that provide the core of the computer science curricula [2,3]. CS1 focuses on basic programming concepts such as

syntax, loops, conditionals, looping, structures and objects, arrays, and pointers. CS2 is an advanced-level programming course that is mandatory for any CS student; and it is usually studied after learning CS1 [4]. CS2 includes records, linked lists, stack, queues, trees, graphs, searching and sorting algorithms [3]. Normally in learning programming, a student has to learn and pass CS1 before learning CS2. That is, CS1 is a prerequisite course for CS2 [5-7]. Partly due to deep abstractions and tacit complexity of algorithms dynamics, novices find CS2 to be a more difficult course to learn than CS1 [4].

Several studies have shown that CS1 is the best predictor for success in CS2 [7-10]. For this reason, some universities restrict students who fail CS1 to directly study CS2 unless they pass CS1 at least with a C grade [7-10]. It is argued that CS1 consists of the topics that are fundamentals for understanding CS2, and whoever fails CS1 is unlikely to learn and successfully pass CS2. Several studies have examined how the success or failure of CS1 affects the performance of CS2 as well. However, to date, there are limited empirical studies that have been done to examine if there exist any specific factors that can influence students who fail CS1 to successfully pass CS2. This study was intended to address such a research gap. Specifically, this study aimed to answer the following research questions: (1) does there exist any substantial percentage of students who fail CS1 but pass C2? (2) Which factors can lead students who pass CS2 to fail CS1? (3) Which factors can influence students who fail CS1 to successfully pass CS2 (4) Does there exist any special traits among the students who fail CS1 but can successfully pass CS2? This paper is organized as follows: Section 2 presents the related works. Section 3 provides the methodology of the study. Section 4 presents the research findings. Section 5 presents the discussion while the conclusion and future research works are presented in section 5.

Related works

Several studies have examined factors that influence student's success/failure of either CS1 or CS2 in different ways. [10] studied the correlations of the individual student's performance patterns in the five programming subsequent courses; and the effect of introductory programming courses upon the subsequent advanced programming courses. They found that success in CS1 did indeed correlate to success in CS2. [8] also studied how much knowledge students retain from a CS1 course before studying CS2 course. They found that majority of students do not retain CS1 concepts. They found also such a situation becomes worse if there is much time elapsed from the time students learn CS1 to the time they begin to learn CS2.

[11] conducted the study to investigate if CS1 grades are the successful indicators of CS2 grades among the students who were pursuing BSc CS course at the University of North Carolina Wilmington. They analyzed the results of C1 and CS2 grades for 2300 students from 2013–2019. They found that CS1 grades appear to have a statistical relationship with CS2 grades. They also found that although students who passed CS1 with higher grades still attained lower grades in CS2.

[5] conducted a quantitative study to examine the factors that influence the success and failure of a CS2 course among the CS and Computer Engineering students at the University of South Florida, USA. Results showed that that CS1 is the best predictor for success in CS2. In another study, [12] found also that CS1 tends to be the predictor of the success or failure of CS2 even if such course is instructed by using different programming languages [12]. Other studies have also reported that there exist some other factors other than the success of the CS1 that have an impact on the CS2 performance. Such factors include students' motivation [12,14], learning environments, and socio-cultural issues [15]. The above-reviewed studies have examined how the success or failure of CS1 affects CS2. While there exist a number of studies that have examined the factors that influence the success/failure of either CS1 or CS2 in different ways, so far there is limited literature that has explored specific factors that can influence the success of CS2 for students who fail CS1. This study was therefore intended to address such research gap.

Teaching of the CS1 and CS2 Course at CIVE

The College of Informatics and Virtual Education (CIVE) is one of the six colleges of the University of Dodoma (UDOM). CIVE was established in 2008. It is responsible for the delivery of Information and Communication Technology (ICT) programmes at all academic levels. The CS1 and CS2 courses at CIVE are studied during the first and second semester respectively, by all first-year undergraduate students.

CS1

The CS1 at CIVE is called introduction to high-level programming. Its course code is CS110. The course has ten (10) credits. This course is learned by all undergraduate students who are enrolled in all ICT-related programmes. C110 is normally instructed in C++ programming language, though other imperative programming languages such as C can also be used. The course covers all the basic concepts of computer programming which include the vari-

ables and variable declarations, data feeding, data processing and outputting, the flow of control and control structures (if, if...else, If... else if, switch/case), iteration (for, while and do-while loop), arrays, functions, pointers, and file handling. The main objective of this course is to introduce to students the general principles of computer programming. Upon completion of this course, students who learn CS110 should be able to implement the basic principles of computer programming; analyze different elements pertinent to programming languages (syntax and semantic), use problem-solving strategies and techniques, design and implement programs in C++. This course has no a prerequisite course. The course is normally taught by using the traditional lecture method with 40 hours lectures, 20 hours tutorials/seminars, 10 hours assignment, 20 hours of independent studies, and 10 hours of practical per semester. The teaching method commonly used is the traditional lecture method. The course instructor is also free to use any supporting teaching tools such as learner-driven or machine-driven visualization tools. The assessment is done by using both continuous assessment (CA) and end-of-semester exam (SE). The CA carries 40% while SE 60%. The CA is usually assessed by using a written test and practical works for CA while the end-of-semester examination is done as a closed book written mode.

CS2

The CS2 course at CIVE has been given the code CS122, with the name data structures and algorithms. The course has 10 credits. C122 is studied during the second semester. In this course, a student will learn structs, stacks, queues, linked lists, binary trees, searching and sorting as techniques. The main objective of this course is to enable students to write well programs that run correctly and efficiently. Upon completion of this course, students should be able to discuss theoretical aspects of data types; structures and algorithms; implement various data structures; such as queues, stacks, trees, graphs implement various algorithms pertinent to operations on structures; and valuate various algorithms against resources, learn infix, prefix, and postfix expressions; and review on the pointer, dynamic memory allocation, and recursion. The prerequisite for CS122 is CS 110. The course is normally instructed by using the traditional lecture methods with 40 hours lectures, 20 hours tutorials/seminars. 10 hours assignment, 20 hours of independent studies, and 10 hours practical per semester.

Grading criteria

The grading criteria for CS1, CS2, and all other courses at CIVE for all undergraduate level programmes are as follows: 0-30:F, 30-

39.9: E, 40-49.9: D, 50-59.9: B, 60-69.9: B+, and 70-100: A. A student who gets a performance below 40% will be required to do a supplementary exam. If the student fails the supplementary examination, he/she will be required to repeat the course in the subsequent year. If it happens the student fails again the same course during the supplementary exam, such student will be discontinued from the studies.

Methodology and Purpose of the Study

Research design

The aim of this study was to examine factors that can influence students who fail CS1 to successfully pass CS2. The study used mixed research design whereby data was collected and analyzed by using both quantitative and qualitative methods. The participants of the study were undergraduate students who were enrolled to study various bachelor degree programmes at CIVE from 2013-2018. Data was collected by means of documentary review, survey questionnaire, and interview methods.

Documentary review

A documentary review of the students' examination reports was done to determine if there exist any substantial percentage of students who fail CS110 but pass C122 between the academic years 2013-2018. The sample size of the documentary review consisted of 10 examination reports from 2013-2018. Among these reports, 5 were CS110, while the remaining 5 were CS122. Quantitative data from the examination reports were analyzed by using descriptive statistics (percentages).

Interview

In order to examine if there existed any special traits among the students who failed CS1 but successfully passed CS2, an interview method was used. More specifically the interview was intended to explore more information from the participants about the factors that can influence students who fail CS1 to successfully pass CS2. The purposive sampling technique was used to select the key informants. The sample size for the interview consisted of the five key informants, who were purposively selected among the students who managed to pass CS2 but initially failed CS1. The criteria used for selecting respondents were first passing CS2 after failing CS1; and their willingness to participate in the interview. Before the interview, participants were informed about the aim of the interview. The data were collected by an interviewer using a pre-tested semi-structured interview guide. Each interview took an average of 20 to 30 minutes. All interviews were conducted either in Kiswahili or

English or both depending upon the willingness of the interviewee. Where necessary more probing, and follow-up questions were introduced in order to get more clarification or additional facts. The interview took place at CIVE. All interviews were audio-recorded. The interviews were later transcribed and interpreted into English and analyzed by using content analysis. In determining how many interviews should be conducted, a saturation theory, as recommended by [16] was used; that is, the researcher continued to gather data from the respondents via interview until no new contribution was obtained from members about the studied topic.

Survey questionnaire

The survey questionnaire was used to collect students’ views pertaining to the factors that influence the failure or success of CS1 and CS2 respectively, among the participants of the study. The questionnaire comprised both open and close-ended questions. Open-ended questions were aimed at giving respondents a wide room for providing information, enabling them to express their perspective views using their own language, terms, and expressions. The closed-ended questions collected demographic data about the respondents. The two open-ended questions asked were: “Which were the main causes of failing CS1?” and another question was: “Which were the main causes of passing fail CS2 despite initially failing CS1?” The population of the study consisted of first-year undergraduate students who were enrolled to study various Bachelor’s degree programmes at CIVE from 2013-2018. The sample size for the questionnaire survey consisted of 113 students out of 151 students who failed CS1 but who managed to successfully pass CS2. The criteria used to select students who would participate in a survey were having successfully passed a DSA course, their willing-

ness to participate in the study, and is available at the college when this study was conducted. Such students belong to the second, third, and fourth year’s classes. Quantitative data from the closed-end questions were analyzed by using descriptive statistics while qualitative data from the open-ended question were analyzed by using content analysis [17]. The Statistical Package for Social Sciences (SPSS) and Microsoft Excel software tools were used during analysis. The questionnaires were self-administered and were given physically to respondents and collected within twenty minutes after being filled in.

Results and Discussion

Failure of CS1 and CS2 at CIVE

Table 1 presents the students’ CS110 and CS122 performance at CIVE five consecutive years from 2013-2018. As shown in table 1, from 2013-2018, a total of 3088 students did their end-of-semester exams for a CS1 course. Among them, 2912 also managed to study and do the end of the semester examination for CS122, while 176 students dropped the course for several reasons such as postponement, healthy problems, discontinuation cases, etc. The average failure rate for CS110 in all five years is 23.93% for CS110 and 19.24% for CS122, respectively. The highest failure rate for CS122 is 40.8 % while the lowest was 6.1%. Likewise, the highest failure rate for CS122 is 28.7 % while the lowest is 10.61%. According to these results, the students who failed C122 were less than those who fail CS1. Table 1 shows that the average failure rate for both CS 122 and 110 was 21.8%, while that of CS 122 was 17.06%. This average is considered to fall within the normal range programming course since programming failure rates are reported to be higher in other colleges to 33% [18].

CS1					CS2					
Year	N	F	P	%F	%P	N	F	P	%F	%P
2013-2014	445	58	387	13	87	435	51	384	11.7	88.3
2014-2015	523	32	491	6.1	93.9	424	45	379	10.6	89.4
2015-2016	637	96	541	15.1	84.9	615	129	486	21.0	79.0
2016-2017	659	269	390	40.8	59.2	637	85	552	13.3	86.7
2017-2018	824	281	540	34.1	65.5	801	230	571	28.7	71.3
Total	3088	736	2349	109.1	390.5	2912	540	2372	85.3	414.7
Average	617.6	147.2	469.8	21.82	78.1	582.4	108	474.4	17.06	82.94

Table 1: General performance analysis of students for cs1 and cs2 from 2013-2018.

Keys: F, implies failed; P, passed; N, sample size.

Students who failed CS1 but passed CS2

Table 2 indicates the detailed the students’ performance analysis for both CS1 and CS2 for five successive years from 2013-2018. Results indicate that a total of 151 students (20.52%) out of 736 students who failed CS1 managed to pass CS2. That is from 2013-

2018, 20.52% of the students who failed CS1 managed to pass CS2, while 79.48 5% failed both. Table 2 further shows that 52 students (10.3%) of the students who failed CS1 passed CS122 with higher grades (B grade and above).

Year	Failed CS1	Failed Cs2	Failed both CS1 and CS2	Percentage FAIL (%)	Failed CS1 but Passed CS2	Percentage PASS (%)	C	B	B+	A
2013-2014	58	51	20	34.48	38	65.52	13	12	11	2
2014-2015	32	45	15	46.88	17	53.13	12	5	0	0
2015-2016	96	129	61	63.54	35	36.46	26	9	0	0
2016-2017	269	50	231	85.87	38	14.13	25	12	1	0
2017-2018	281	230	258	91.81	23	8.19	23	0	0	0
Total	736	505	585	79.48	151	20.52	99	38	12	2

Table 2: Detailed students’ performance analysis for CS1 and CS2 from 2013-2018.

Results shown in table 2 indicate that just one out of five students who failed CS1 managed to pass CS2; and one out of every 14 students who initially failed CS1 managed to get higher grades in CS2 than CS1.

Major causes of the CS1 failure

Before we explored the specific factors that could influence the success of the CS2 among the students who failed CS1, we asked the students who failed CS1 to outline the main causes of failing CS1. Table 3 presents eight (8) major causes of failing CS1 for students who successfully passed CS2, which are listed based on the decreasing order of the students response in percentages: Fear that programming is difficult (92.9%);changing of the learning environment (90.3%); relying heavily on rote learning (86.7%); lack of students’ commitment toward learning (57.5%); changes of the teaching strategy (83.2%); students’ irregular class attendance (66.4%); lack of cooperation with other students (58.4%); and lack of the students' background in ICT skills (47.8%).

Factor	No. Respondents	Percentage
Having fear that programming is difficult	105	92.9
Changing of the learning environment	102	90.3
Relying heavily on rote learning	98	86.7
Lack of students’ commitment towards learning	65	57.5
Changes of the teaching strategy	94	83.2
Students’ irregular class attendance	75	66.4
Lack of cooperation with other students	66	58.4
Lack of the students’ background in ICT skills	54	47.8

Table 3: Students’ responses on the major causes of the cs1 failure from the survey (Data are the Percentage of all student respondents, N = 113).

Factors that Influence CS2 Success

Table 4 shows that seven (7) factors were identified as the key success factors that enabled students who failed CS1 to pass CS2. As shown in Table 4, being confident after failure was the leading factor that influenced the success of CS2, as it was reported by over 95% of all respondents. Unlike many others, the majority of the students who managed to pass CS122 after failing CS1 didn’t lose hope

that they cannot learn and successfully pass CS2. The next factor, as indicated in table 4, was revising threshold programming concepts. This strategy was reported by over 91% of all respondents. Such

students reported that they strongly revised programming thresholds before and starting to learn CS2. The ability of the student to change their study habit is another factor that influenced the students CS2 success. This factor was reported by 86.7% of the total respondents.

Factor	No. Respondents	Percentage
Being confidence after failure	108	95.6
Reviewing introductory programming threshold concepts	103	91.2
Changing study habits	98	86.7
The use of scaffolding technique	65	57.5
Attending discussion after doing self-learning	76	67.3
Using education visualization tool	75	66.4
Avoid rote learning	64	56.6

Table 4: Students’ responses on the factors that influence the success of the cs2 failure from the survey (Data are the Percentage of all student respondents, N = 113.)

Other factors which were identified to help students pass CS2 during the survey were as follows:- The use of scaffolding technique (57.5%); attending discussion after doing self-learning (67.3%); using education visualization tools (66.4%); and avoiding rote learning (56.6%).

Special traits

In order to examine if there exists any special personal traits or attitude after getting data from the survey, five students were also contacted and interviewed about the the factors that influence students who failed CS1 to pass CS2. All five students interviewed agreed that the main reasons why they think they managed to pass CS2 is because first they asked themselves why they have failed, while other students have passed. They also said that the next reason was building a confidence that if such students work hard they will pass; and lastly they said that they dint give up nor matter how difficulties they perceived when learning. For example, during the interview, when one student was asked why she managed to pass CS2 despite the belief that a student who fails CS1 cannot pass CS2

she responded as follows: “After arriving I was told by other that, ooh!, CS110 is a very tough subject just count you have already got supplementary of CS110. I was very demoralized, then I failed. But later, I asked myself, why others have passed? What about those who write programming books or invent programming? Are they not people? Why should I fail to program? Then I did a very strong review of introductory programming. I did many exercises. Later I managed to pass CS2. And even when I came for CS110 supplementary exam, I also passed”.

The above of students’ responses show that students who passed CS2 after failing CS1 had self-efficacy and were giving up after failure. Documentary analysis of the students CS1 examination further showed that all students who passed CS2 were able to pass CS1 supplementary examination.

Discussion

The aim of this study was to examine factors that influence the CS2 success among undergraduate students who failed CS122 at CIVE from 2013-2018. Results from the study indicates that about one out of every twenty first-year undergraduate students at CIVE who failed CS1 managed to pass CS2; and one out of every 14 students managed to get higher grades in CS2 than CS1. This is a substantial number of students since if such students were not allowed to study CS122 after failing CS122, they would probably lose hope drop out the course.

Results from the study also identified eight (8) major causes of failing CS1. Such causes are fear that programming is difficult; changing of the learning environment, relying heavily on rote learning; lack of students’ commitment toward learning, changes of the teaching strategy; students’ irregular class attendance; lack of cooperation with other students; and lack of the students' background in ICT skills. Responses from the study haves shown. Such findings are similar to that of [13], however in this study it is noted that, among all the factors identified, fear that programming is difficult seems to have a detrimental impact on the successful learning of programming courses among junior students. Students reported that immediately after arriving at the university they were threatened by the senior students that the majority of them will fail CS1. They were therefore disheartened that no matter which effort they apply, they would fail the course. As a result, such students tend to lose hope and interest, thinking that they will not understand how to program. The fear that programming is difficult, and how it affects learning to program has been reported by [19].

After having low motivation, due to the created fear, the majority of students who failed CS1 reported that the only learning approach that they used was relying heavily on rote learning. This method was used because such students had lost the hope that they can understand to program. As stated by [19], the last surviving “bullet” in his struggle towards passing the programming exam for any demotivated student who fails to understand programming, is to memorize codes and programming examples.

Results also from the study also has also identified the following as the key factors which led the students success: Being confidence after failure; Reviewing introductory programming concepts; Changing study habits; The use of scaffolding technique; Attending discussion after doing self-learning, Using education visualization tool; and Avoid rote learning. In addition, results from the study during interview revealed that students who managed to pass CS2 had a self-efficacy attitude and were not giving up after failure.

Previous studies have reported that failure of programming course is largely attributed to poor teaching methodology [20] and poor student’s background in ICT and Mathematics [21]. However, in this study psychological factors such as fear, lack of student’s confidence, and poor student’s attitude before and after the failure of CS1 seem to have a greater effect on the success/failure of any programming course. This is evidenced by the fact that students who managed to pass CS2 are those who managed to build a positive attitude and changed their study habits after failing CS1.

Findings have shown that students who failed CS1 but later passed CS2 seem to have general characteristics of not giving up after initial failure. For example, one female student reported during the interview that after failing CS1 she asked herself why she failed and why other passed. She then started to build confidence that she could also pass CS2. Thus, regardless of just reviewing the materials, and working hard, the existence of the belief that that someone can do something and succeed is what is missing for majority of students who study programming courses. Contrary to what was reported by [22] that there are some students who will never understand how to program, this study has revealed that it is student’s courage and self-efficacy attitude that someone can program that always matters. According to Bandura (1986), once a student attains self-efficacy attitude, he/she can work hard and devise any learning strategies for better performance outcomes regardless of their initial failure. These findings concur with [19] who stated that “If students approach a course with an expectation that it will be difficult, and with a negative image of those who excel in the subject, it is very hard to imagine them as being especially.

Conclusion and Future Studies

In this study, we have examined factors that influence the CS2 success among 151 undergraduate students who initially failed CS1 for five consecutive years from 2013-2018 at CIVE. Both qualitative and quantitative data collection and analysis methods were used. Results show that a combination of personal factors, psychological factors, and learning strategies had a positive impact on the students CS2 success. Reflecting on these results, we argue that students who fail CS1 can successfully pass CS2 if they are given the appropriate psychological support to help them build new confidence after their initial failure. An important lesson that we have learned in this study is that instructors who teach programming courses are advised to increase more efforts towards building confidence and interest among the students who learn programming courses. We hope that the insights provided in this study will influence computer programming course instructors to introduce new strategies to motivate students who fail programming course tests so that they don’t hate the lesson and lose hope of success. The study recommends instructors who teach programming courses to introduce new teaching strategies that encourage self-efficacy and motivation attitude among the students. In this study, we have only examined factors that can influence the success of the CS2 among the students who failed CS1 in just one institution. In the future, we expect to conduct a longitudinal study to examine factors that influence low motivations among the students who study programming courses for more than ten institutions that teach computer programming courses in Tanzania.

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Conflict of Interest

Declare if any financial interest or any conflict of interest exists.

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